Rattlesnake Creek Conceptual Rehabilitation Plan

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The Rattlesnake Conceptual Rehabilitation Plan represents the efforts of numerous individuals from several state and federal agencies, the Asotin County Conservation District, and the Nez Perce Tribe. We would like to thank the landowners within the basin that granted access to their property to complete field assessments and met with us to discuss concerns and expectations. We would also like to thank the Rattlesnake Creek Assessment Team members who participated in the field assessments, collected data, and provided reviews of this report.

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1 INTRODUCTION

Rattlesnake Creek is a tributary to the Grande Ronde River in southeast Washington (Appendix Figure 1). The creek supports Endangered Species Act (ESA) listed summer steelhead (*Oncorhynchus mykiss*), and is included in the Grande Ronde River major spawning area (MaSa) by the Snake River Salmon Recover Board Regional Technical Team (SRSRB, 2011). ESA-listed bull trout (*Salvelinus confluentus*) are also likely present, although very little information on fish population status is available. Rattlesnake Creek is commonly included as part of the lower tributaries to the lower Grande Ronde River in sub-basin plans and assessments, so information regarding the creek is often within the context of surrounding tributaries (e.g., NOAA, 2016; Nowak, 2004; SRSRB, 2011).

Sage Environmental Research, LLC was contracted by the Asotin County Conservation District (ACCD) to develop a brief condition assessment and conceptual rehabilitation plan for Rattlesnake Creek. The condition assessment builds on a field assessment conducted on July 12, 2017 by natural resource specialists from the Natural Resource Conservation Service and Washington Department of Fish and Wildlife. A second field assessment was completed in late October 2017 by the Rattlesnake Creek Assessment Team to document current habitat conditions and identify potential locations for rehabilitation actions. Data and observations from the field assessments were used to develop this conceptual rehabilitation plan. Project actions proposed in this plan will encourage natural improvement of the creek's geomorphology and available fish habitat.

1.1 Purpose

The impetus for the conceptual rehabilitation plan was the result of a catastrophic flood and debris flow impacting the channel and floodplain of Rattlesnake Creek on April 13, 2017 (Hoyle-Dodson and Ordonez, 2017). The flood released approximately 9.5 million gallons of water over a short period of time, which altered the creek's morphology, channel and floodplain substrate characteristics, bed stability, and removed most of the riparian vegetation, top soil, and large woody debris (LWD) along nearly seven river miles. The purpose of this plan is to:

- Compile a summary of Rattlesnake Creek basin characteristics
- Identify and map rehabilitation reach breaks based on apparent condition and the expected timeline for recovery
- Develop a conceptual rehabilitation plan for delineated reaches, inclusive of maps and written prescriptions

1.2 Rehabilitation vs Restoration

The terms rehabilitation and restoration are often used interchangeably, but the difference in their definitions provides the basis for setting achievable goals within this plan. Stream rehabilitation includes project actions that aim to assist a stream to adjust towards a healthy and sustainable improved condition (Brierley and Fryirs, 2012). Whereas stream restoration project actions aim to return a system to an earlier state or condition (often prior to human disturbance). Based on the natural boundary controls, magnitude of disturbance caused by the flood, and the system's current instability, identifying realistic and achievable restoration goals would be difficult. In contrast, there are abundant opportunities identified in this plan to rehabilitate Rattlesnake Creek by working with natural processes to promote a positive trajectory in condition.

1.3 Limitations

This report was prepared as a tool for ACCD and landowners to identify rehabilitation opportunities that are appropriate within the context of Rattlesnake Creek's current condition and natural boundary controls. The information provided in this report is based on limited publicly available data and brief field assessments that were attainable at the time of writing this report. Because of the magnitude of disturbance from the flood on April 13, 2017, it is likely that site conditions will change with time and subsequent high flow events. The recommended project actions in this plan identify immediate opportunities for rehabilitation and should be completed over the next 1-3 years. The project actions are concepts that will require further development and vetting by landowners and potential funders before being implemented. As the scope of projects are defined, they may also require permits and engineered designs. Future assessments, recommendations, and actions will likely be necessary as the affected areas change and respond to high flow events and early rounds of implementation.

2 BASIN OVERVIEW

Rattlesnake Creek is a tributary to the Grande Ronde River in Asotin County in the southeast corner of Washington State (Appendix Figure 1). The creek drains from the south slope of the Blue Mountains and the basin encompasses 16.75 square miles (mi^2; Table 1). The main channel is approximately 6.8 miles long with multiple tributaries, the largest being the West Branch of Rattlesnake Creek, entering the mainstem at river mile (RM) 1.7. The basin is pear-shaped with a dendritic stream network and steep hillslopes. High elevations are forested, and the main channel was densely covered by immature alder prior to the flood (SRSRB, 2011).

Table 1. Relevant characteristics of the Rattlesnake Creek basin. Results were calculated and summarized using the USGS Stream Stats tool (https://streamstats.usgs.gov/ss/).

Parameter Description	Value
Drainage Area	16.75 mi^2
Maximum - minimum elevation	3,600 ft
Maximum basin elevation	4,880 ft
Minimum basin elevation	1,280 ft
Mean Basin Elevation	3,460 ft
Basin-wide mean annual precipitation	17.3 in
Percentage of drainage area covered by canopy	30.4%
Percent area with slopes greater than 30 percent from 30-meter DEM	55.8%
North-Facing Slopes Greater Than 30 Percent	7.74%
Mean basin slope computed from 30 m DEM	34.2%

2.1 Geology and Soils

Geology in the Rattlesnake Creek basin is dominated by Columbia River Basalt flows from the Grande Ronde, Saddle Mountains, Wanapum, Weissenfels Ridge, Eckler Mountain, Buford, Roza, and Umatilla members during the Miocene epoch (5 - 23 million years ago; Appendix Figure 2). Basalt outcrops are exposed on the valley margin in many areas along the mainstem and act as a primary control on the creek's gradient and planform. Knick points along the mainstem appear on the surface as bedrock canyon sections with exposed basalt directly against the channel (e.g., RM 0.8 to 0.9 and RM 1.2 to 1.4). Soils in the basin are dominantly silty, sandy, and stony loams of various complexes (primarily loess and basalt colluvium; Appendix Figure 3). Areas near the valley margins of the mainstem and tributaries typically have a higher proportion of colluvium derived from basalt, while soils at higher elevations typically have a higher proportion of loess. Cropland is generally restricted to rare instances of Cloverland silt loam, a soil of statewide agricultural importance. Most of the soils are well drained and best suited for bunchgrasses, fescues, and other native grasses, forbs, and shrubs.

2.2 Land Cover

The Rattlesnake Creek basin is dominated by evergreen forest and grassland/herbaceous cover (Table 2). Evergreen forests are located primarily in the upper elevations and fringes of the basin while grassland/herbaceous cover is the dominant land cover at moderate elevations along hillslopes and ridge tops in the middle of the basin (Appendix Figure 4). Areas in the basin that are described as developed are typically roads and highways. There is little crop cultivation, and most is in one patch in the northwest corner of the basin.

Table 2. Land cover by proportional area within the Rattlesnake Creek basin, derived from the National Land Cover Database (Homer et al., 2015).

Land Cover	Proportional Area
Evergreen Forest	46.4%
Grassland/Herbaceous	32.2%
Shrub/Scrub	15.9%
Developed, Open Space	3.4%
Cultivated Crops	1.5%
Developed, Low Intensity	0.5%
Emergent herbaceous Wetlands	<0.1%
Developed, Medium Intensity	<0.1%
Mixed Forest	<0.1%

2.3 Hydrology

There are no flow gauges in the Rattlesnake Creek basin, so a USGS regional regression curve was used to estimate flood recurrence intervals. These estimates are often inflated for ungauged streams in southeast Washington state, so it is likely that the true discharge for the flood recurrence intervals in Table 3 are lower. Nevertheless, it should be noted that the estimated peak discharge during the flood was 2,507 cubic feet per second (cfs), nearly 1000 cfs higher than the predicted 100 year flood (Hoyle-Dodson and Ordonez, 2017).

Table 3. Discharge estimates in cubic feet per second for recurrence intervals for the Rattlesnake Creek basin. Estimates were calculated and summarized using the USGS Stream Stats tool (https://streamstats.usgs.gov/ss/).

Recurrence Interval (year)	Estimated Discharge (cfs)	Standard Error (%)
2	146	80
10	547	57
25	872	55
50	1180	55
100	1530	56

2.4 Land Ownership

Most of the Rattlesnake Creek basin is privately owned (Table 4). The upper northeast corner of the watershed is within the boundary of the Umatilla National Forest and is the only area that is federally owned. The headwaters of the West Branch of Rattlesnake Creek are within the national forest boundary. State land within the watershed is limited to Field Springs State Park, in the northwest corner of the watershed (Appendix Figure 5).

Table 4. Land ownership by proportional area of parcels in the Rattlesnake Creek basin and parcels affected by the flood on April 13, 2017.

Ownership	Rattlesnake Creek Watershed	Flood-Affected Parcels
Private	87.1%	86.1%
State	5.6%	13.9%
Federal	7.3%	-

3 REHABILITATION OBJECTIVES

The primary rehabilitation objective for Rattlesnake Creek is to improve habitat conditions for ESA-listed species by promoting the recovery of natural fluvial geomorphic processes that create and maintain a self-sustaining ecosystem. Project actions that target limited or disconnected processes will improve abiotic conditions including water quality parameters such as temperature, dissolved oxygen, and turbidity. Based on natural boundary conditions and the magnitude of disturbance caused by the flood, natural recovery of the system will be relatively slow. Therefore, the conceptual rehabilitation projects in this report aim to improve fish habitat conditions in the short term (1-5 years) and decrease the timeline for ecosystem recovery in the long term (5+ years).

3.1 Limiting Factors

There is insufficient information to determine the status and trends of ESA-listed species in Rattlesnake Creek. However, ESA-listed steelhead were present and observed prior to the flood (EAP, 2016: Rattlesnake Creek WAM06600-032101 Provisional Data). Rattlesnake Creek is one of many streams included as part of the lower tributaries to the lower Grande Ronde river. Therefore, there is little information available describing limiting factors specific to the Rattlesnake Creek basin, as it is lumped with other lower tributaries. The lower Grande Ronde tributaries were identified in the Grande Ronde Subbasin Plan as a priority for restoration of steelhead habitat by the Ecosystem Diagnosis and Treatment model (EDT; Nowak, 2004). The primary limiting factors identified in Rattlesnake Creek by the Northeast Oregon ESA Recovery Plan are outlined in Table 5. Based on field observations, these limiting factors to ESA-listed species are still relevant and have likely been exacerbated by the flood.

Table 5. Primary limiting factors and threats for steelhead in the lower tributaries of the lower Grande Ronde river. Adapted from NOAA, 2016.

Primary Limiting Factors	Threats	Life Stages Affected	Viability Parameters Affected
• Excess fine sediment • Water quality (high summer temperatures • Impaired riparian condition • Reduced habitat quantity/diversity (LWD) • Fish passage • Low summer flows (due to upstream withdrawals) • Insufficient fish and habitat data	• Agricultural activities • Livestock grazing • Timber harvest • Roads	• Incubation • Juvenile rearing	• Abundance • Productivity

4 REACH DELINEATION

4.1 Methodology

Reaches were delineated using valley gradient breaks, surficial geology, results from the field assessments, observed geomorphic and habitat conditions, and an expected timeline for recovery. Valley gradient was calculated using a flow accumulation stream network delineated from a 30 m Digital Elevation Model (DEM), and major gradient breaks were identified. Combining valley gradient breaks and stark differences in surficial geology provided the first cut of reach breaks. Reach breaks were further refined from field assessment observations including sections of subsurface flow, potential fish barriers, relative riparian/channel/floodplain conditions, and locations of LWD pieces (Table 6). Within the scope of this project, a full geomorphic assessment was not feasible; therefore, this approach allowed us to identify reaches based on major geomorphic controls and expected timeline for recovery, so we can focus rehabilitation efforts where they are most needed.

Nearly seven miles of the mainstem of Rattlesnake Creek was impacted during the flood. However, the magnitude of flood damage varies among reaches. The expected timeline for recovery is based on results from the brief assessments and the expert opinion of the Rattlesnake Creek Assessment Team. We define ‘recovery’ as improved geomorphic and habitat conditions to the extent that natural processes can sustain the improved condition. The relative timelines are based on the expectation that the recommended actions in the conceptual rehabilitation plan are fully implemented.

Table 6. Summary of delineated rehabilitation reaches and their relative timeline for recovery in Rattlesnake Creek.

Reach	Extent	Length (RM)	Mean Gradient (%)[a]	Basin Area at Downstream End (mi^2)[b]	Major Tributaries	Timeline for Recovery
1	RM 0.0 to 1.4	1.45	5.0	16.75	Unnamed on river left at RM 0.8	Short (5-10 years)
2	RM 1.4 to 3.3	1.85	7.9	15.32	West Branch Rattlesnake Creek on river right at RM 1.7	Medium (10-20 years)
3	RM 3.3 to 4.0	0.71	11.8	5.51	Two unnamed on river right at RM 2.7 and 2.9	Long (20-50 years)
4	RM 4.0 to 6.1	2.08	9.5	3.94	None	Long (20-50 years)
5	RM 6.1 to 6.8	0.71	4.9	0.92	None	Medium (10-20 years)

Notes:
[a] Mean gradient was calculated using 30m resolution DEM
[b] Upstream basin drainage area was estimated using USGS Streamstats v4 (2016)

5 PROJECT ACTION CATEGORIES

The project actions recommended in this plan will promote the recovery of watershed processes that help maintain a sustainable ecosystem. The actions address common limiting factors and other immediate concerns that inhibit the ability of the stream to recover naturally. Recommended actions are described within the context of each project area and highlighted in the conceptual project maps in the appendix.

5.1 Remove Fish Passage Barriers

Several fish passage barriers were identified during the field assessments and should be addressed immediately as they may pose an imminent threat to ESA-listed species. Most of the identified barriers are complete blockages by boulders, cobble sheets, woody debris jams, or exposed bedrock ledges. These types of barriers can be addressed through channel alteration, structure placement, or direct removal of boulders and debris. Sections with subsurface flow also represent seasonal passage barriers, and are most prominent in the upper reaches. Subsurface sections are typically within expansive gravel and cobble sheets deposited during the flood and will likely require multiple approaches and more time to be appropriately remedied.

5.2 Riparian Enhancement

Riparian enhancement actions include riparian plantings, invasive vegetation control, and floodplain connection. Riparian vegetation reduces solar radiation input reaching the stream channel and moderates stream temperatures (e.g., Ebersole, 2001; Ebersole et al., 2003). High water temperatures reduce survival of cold-water fish species by increasing exposure to pathogens, disrupting bioenergetics, and impairing food sources. Because the flood removed most of the riparian vegetation, riparian enhancement should be considered in all project areas. Most of the topsoil in the floodplain has been removed, so identifying suitable sites for immediate riparian plantings is a challenge. However, with improved channel and floodplain interaction, high flow events, and adequate fine sediment delivery, suitable soils will accumulate on the floodplain and provide more opportunities for riparian plantings. Invasive vegetation will likely establish early and may outcompete native species; therefore, invasive species should be targeted for removal. We identified areas that may be suitable for immediate planting projects, but riparian enhancement should also be included in conjunction with channel and floodplain complexity projects.

5.3 Improve Channel and Floodplain Complexity

Structural elements such as LWD, boulders, and riparian vegetation are correlated to geomorphic and hydraulic diversity in alluvial systems (Wheaton et al., 2015). The interaction between high flow hydraulics and structural elements helps create and maintain bedforms in the channel (e.g., pools and bars) and floodplain (e.g., side channels, flood-outs). Over time they also influence channel planform and floodplain connectivity by directing flows and reducing sediment transport time by encouraging deposition. Structural elements also provide an immediate biological benefit by creating critical habitat features and providing hydraulic refuge and cover for juvenile and adult salmonids. The current lack of LWD and riparian vegetation will hinder the recovery potential in Rattlesnake Creek. Boulders are still prominent, but are distributed randomly and not functioning to their full potential. Improving floodplain connectivity will likely improve the success of riparian enhancement actions as well. A combination of both materials should be considered, but the recommended conceptual actions in this report suggest the primary material used in each project area.

5.3.1 Large Woody Debris Additions

The addition of LWD is suitable for most project areas in Rattlesnake Creek. LWD may be added as individual pieces, secured jams and complexes, or engineered log jams that are determined to be appropriate during project-level planning. LWD should be added in high densities to increase the overall impact and promote continuous sections of improved habitat. In bedrock canyon sections, LWD may not be appropriate due to increased stream power which will reduce the longevity of structures. There are numerous LWD sources along the valley margin identified during the field assessments that should be returned to the valley bottom. The remoteness of some reaches will make acquiring LWD difficult, so other options should be considered (e.g., transport by truck or helicopter).

5.3.2 Boulder Reorganization

Boulders are still prevalent in all reaches, but are often randomly distributed in the valley bottom or conversely, deposited as large berms along the channel margin. In a high gradient system like Rattlesnake Creek, boulders are often organized in the form of ribs, creating a step-pool morphology. Over time, boulders will naturally reorganize into a similar form if future floods have the competence to move large material; however, a similar morphology can be attained by directly manipulating boulder complexes. Aside from reorganizing boulders to improve fish passage, boulders can be used to effectively improve hydraulic and geomorphic complexity, particularly in bedrock canyon sections with higher stream power.

5.3.3 Large Woody Debris and Boulder Combination

In natural systems, LWD and boulders often work together to create complex and relatively stable debris jams. We recommend that boulders are used to improve the stability of LWD pieces and structures when possible. However, we identified sections where an explicit combination of materials would expedite the implementation of projects based on materials that are available on-site. Additionally, these sections typically have a higher gradient so LWD structures should be secured to increase longevity.

6 Reach 1 Conceptual Projects

Reach 1 is located from RM 0.0 at the confluence with the Grande Ronde River and extends 1.45 miles upstream to the Highway 129 crossing. Approximately 0.03 RM upstream of the Grande Ronde confluence, the creek flows under a private bridge. The reach is entirely within private lands. Very few canopy tree species are present in the valley bottom, except for the top 0.1 mile downstream of the Highway 129 bridge crossing. The canopy that is present is dominated by alder with a few individual ponderosa pines near the floodplain margin. A small unnamed tributary enters the reach on river left near RM 0.8. The entire length of Reach 1 flows along-side Highway 129. The reach is naturally confined, but turnouts for the highway are forcing pinch points, locally increasing confinement and gradient, creating steps in the channel bedform. Bedrock and boulder steps may be fish passage barriers during low flow. Most of the topsoil on the floodplain is absent, but there are pockets remaining that are occupied by invasive species.

6.1 Project Area 01 (RM 0.0 to 0.5)

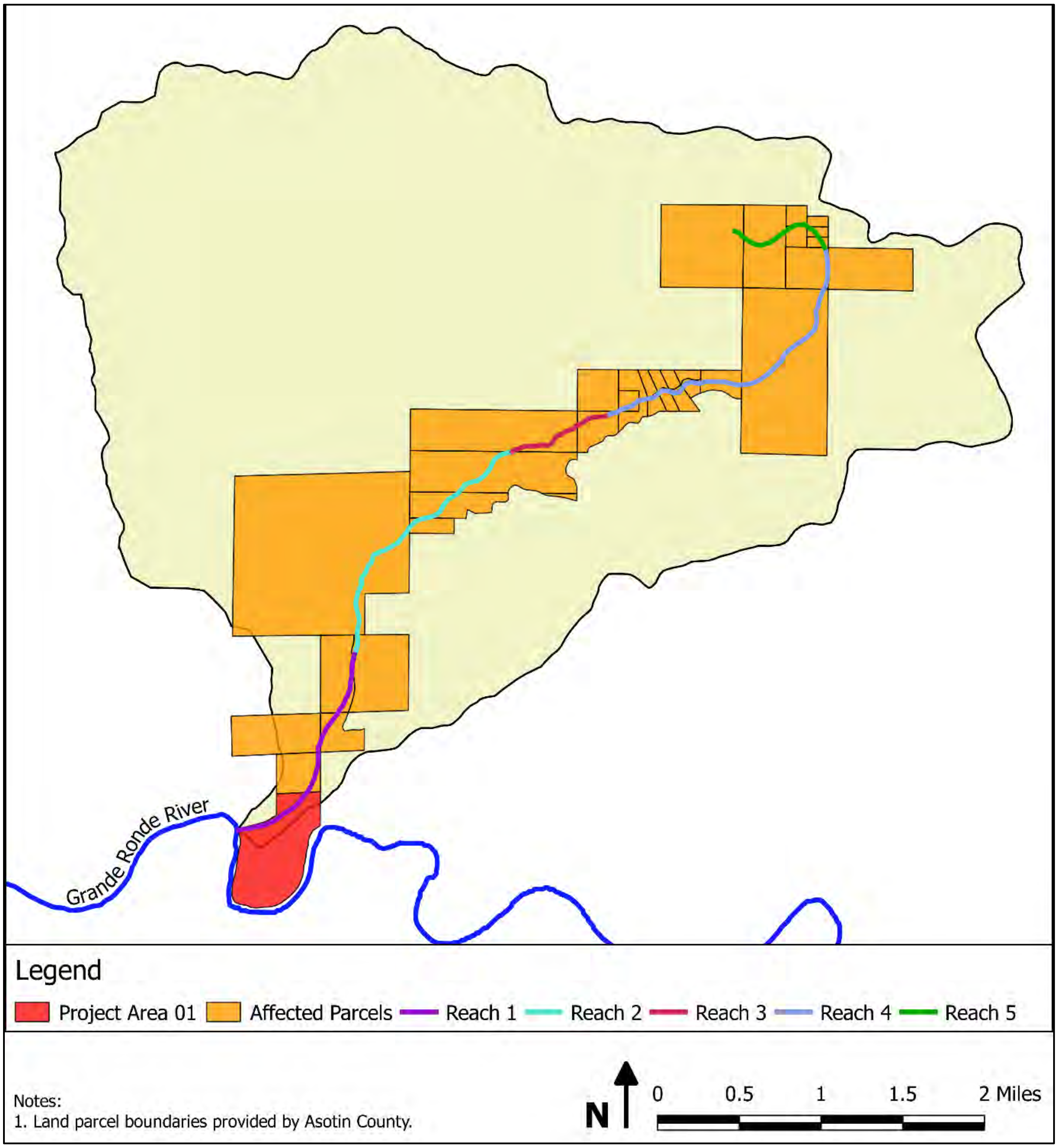

Figure 1. Location of Project Area 01 within the Rattlesnake Creek basin.

6.1.1 Site Description

Project Area 1 (PA-01) is located from the confluence of the Grande Ronde (RM 0.0) to RM 0.5 (Figure 1). The channel is characterized as a confined, low sinuosity, step-pool and plane bed assemblage, heavily influenced by boulders and bedrock ledges. Highway 129 likely has little influence on the planform and behavior of the creek, but likely has some influence on sediment contribution. Multiple bedrock and boulder ledges are exposed and are potential fish barriers during low flow. Very little LWD is within the channel and floodplain; however, approximately 160 pieces of LWD are lodged on the toe of the hillslope above the valley bottom.

The lower 0.2 RM is more confined and incised than the upper 0.3 RM, with only a few floodplain pockets (Figure 2a and b). The upper 0.3 RM is slightly wider, has a lower gradient, and more opportunities for floodplain access and development (Figure 2c and d). A fan consisting primarily of boulders and large cobble has developed at the bottom of this reach and extends into the main channel of the Grande Ronde. The riparian area is devoid of canopy species and invasive herbaceous plants are the dominate vegetation.

Figure 2. Project Area 01 of Rattlesnake Creek looking towards the Grande Ronde confluence (a), upstream from the Grande Ronde confluence (b), and looking downstream (c) and upstream (d) near RM 0.4.

6.1.2 Conceptual Project Actions

Recommendations for PA-01 are to remove the barrier caused by the fan at the Grande Ronde confluence, improve fish passage at potential boulder and bedrock barriers, move lodged LWD back into the channel and floodplain, riparian planting, and invasive vegetation control.

6.1.2.1 Geomorphic Implications

The lower 0.2 RM and portions of the upper 0.3 RM have become incised, and may pose a risk of head cutting without sufficient structural elements to slow water and sediment transport time. Additional LWD in the channel will increase the retention of bedload sediment to reduce incision between RM 0.0 and 0.2, and promote bed scour from RM 0.3 to 0.5 to increase pool frequency. Adding LWD to the floodplain will encourage deposition of fine sediments during high flow events, to improve the potential for future riparian vegetation recruitment and planting opportunities.

6.1.2.2 Biological Benefits

Adding LWD to the channel will increase habitat complexity by sorting sediment to increase spawning opportunities for adult salmonids and concealment areas for juvenile salmonids, and scouring for maintaining pool habitat. LWD will also provide refuge from predators and high-flows. Over time, more floodplain connection will encourage natural recruitment of woody species, and encourage riparian recovery.

The fan at the mouth of Rattlesnake Creek may be eroded by stream and ice flows on the mainstem Grande Ronde over the next few high flow events. It is unlikely that a typical high flow event on Rattlesnake Creek will have the competence to move the material alone. Therefore, the fan should be monitored to ensure that it is not a fish passage barrier during low flows. Likewise, improving passage at the boulder and bedrock ledges that were identified during the assessment would ensure migrating salmonids can move through to upper reaches.

6.1.2.3 Potential Challenges

Getting heavy equipment into the channel to move or add LWD and boulders would be very difficult and would likely create more disturbance at the site. Invasive vegetation has already established, so controlling weeds while establishing native vegetation may be a challenge. The project will require landowner’s acceptance.

6.2 Project Area 02 (RM 0.5 to 1.45)

6.2.1 Site Description

Project Area 02 (PA-02) is located from RM 0.5 to the Highway 129 bridge crossing at RM 1.45 (Figure 3). Confinement is variable, with relatively wide sections (Figure 4a) separated by brief bedrock canyons and deeply incised sections (Figure 4b). The creek flows alongside Highway 129, which increases confinement in localized areas near turnouts. Confined sections are dominated by a step-pool morphology forced by bedrock ledges and large boulders. Wider sections are dominated by a plane bed morphology with occasional multiple threads and brief pockets of diverse hydraulics forced by boulder ribs.

Canopy tree species in the valley bottom are rare for most of PA-02, consisting of alder and ponderosa pine near the valley margin, except for the upper 0.1 miles which appears to have been protected from the flood by the Highway 129 bridge. There are approximately 370 pieces of LWD lodged on the toe of the hillslope above the valley bottom, and near the floodplain margin.

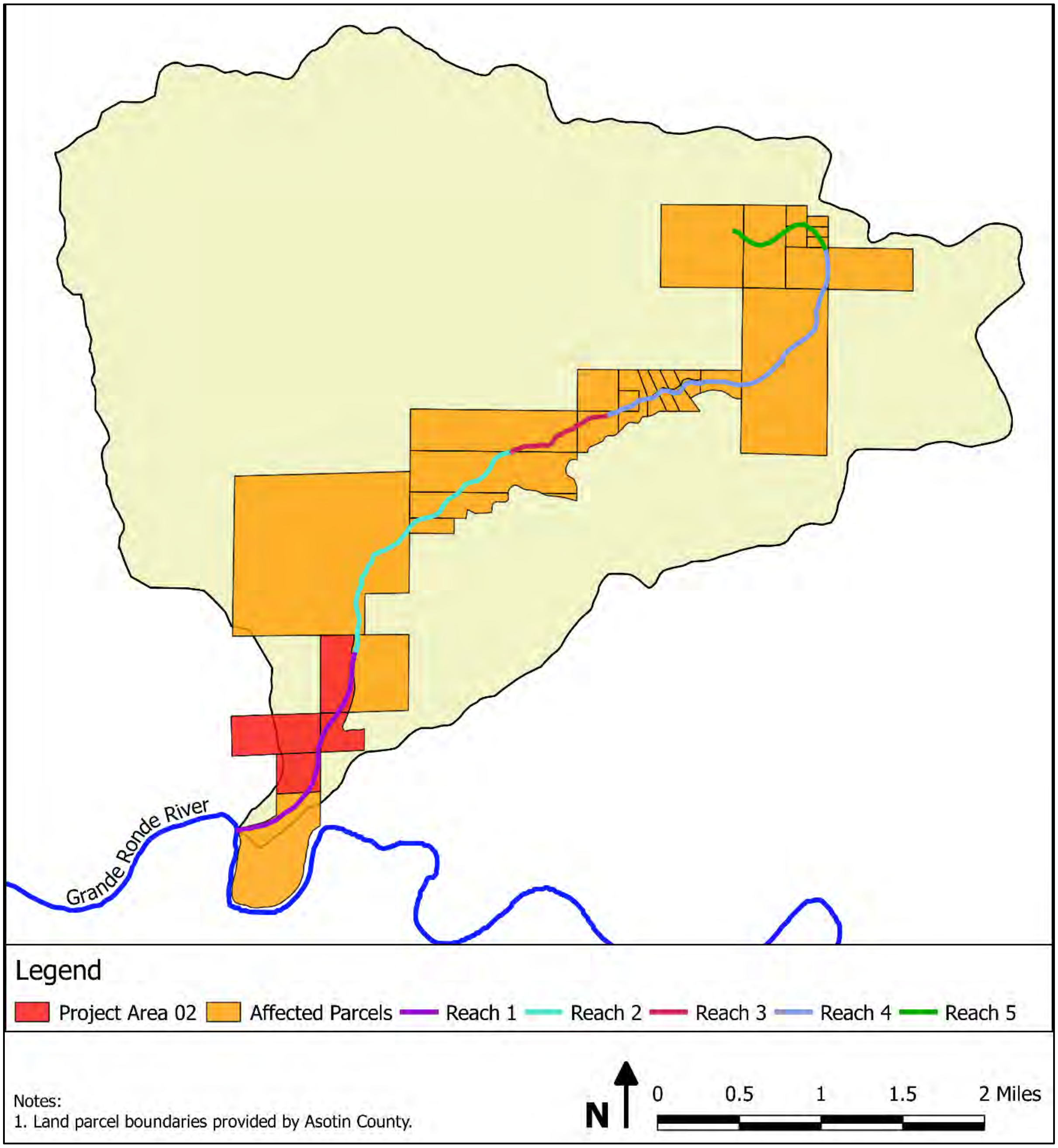

Figure 3. Location of Project Area 02 within the Rattlesnake Creek basin.

a. b.

Figure 4. Views looking downstream in Project Area 02 in a relatively wide section (a) and a confined bedrock canyon section (b).

6.2.2 Conceptual Project Actions

Recommendations for PA-02 are to move lodged LWD into the channel and floodplain in wider sections, reorganize large boulders in bedrock canyon and confined sections, riparian plantings where feasible, and invasive vegetation control.

6.2.2.1 Geomorphic Implications

Within the wider sections of PA-02, adding LWD to the channel will reduce water and sediment transport time by trapping bedload sediment and encouraging floodplain connection. LWD in the channel will increase hydraulic diversity and sediment sorting which leads to increased depositional and erosional features such as bars and pools.

LWD within bedrock canyon and incised sections may become mobile during high flow events; therefore, reorganizing large boulders would be more suitable. Boulders within the channel and along the channel margin would serve the same purpose as LWD by increasing hydraulic diversity, but are likely to remain in place longer in areas with higher stream competence.

6.2.2.2 Biological Benefits

LWD and boulder additions to the channel will provide immediate benefits for juvenile fish rearing in PA-02 by providing predator and high-flow refuge. Migrating and spawning adult fish will also benefit from water velocity breaks and increased sediment sorting which creates potential spawning habitat.

LWD on the remaining floodplain pockets will encourage fine sediment deposition during high flow events, increasing the prevalence of top soil suitable for native plant species. Riparian plantings in the areas identified during the assessment will help stimulate recovery by establishing native canopy tree species.

6.2.2.3 Potential Challenges

Heavy equipment will be difficult to get into the valley bottom to complete work and would cause more disturbance to the site. The project will require landowner acceptance.

7 REACH 2 CONCEPTUAL PROJECTS

Reach 2 is located from RM 1.45 at Highway 129 crossing and extends 1.85 miles upstream to the confluence with an unnamed tributary on river left at RM 3.3. The reach is entirely within private lands. Very few canopy tree species are present and are only present along the valley margin and there is little topsoil on the floodplain. The few pockets of topsoil remaining after the flood are dominated by invasive herbaceous vegetation. The West Branch of Rattlesnake Creek enters the reach at RM 1.7 and was undisturbed by the flood, except for the mouth, which is currently blocked by debris and racked LWD. The overall gradient through the reach is relatively steep (7.9%); however, there are long sections with moderate gradient and sinuosity. Large bedrock ledges and steps create knickpoints in between the moderate gradient sections.

7.1 Project Area 03 (RM 1.45 to 2.4)

7.1.1 Site Description

Project Area 03 (PA-03) is located from the Highway 129 Bridge crossing at RM 1.45 and ends at RM 2.4 (Figure 5). The channel is characterized as partly confined, low-moderate sinuosity, dominated by rapids, runs, and step-pool sequences (Figure 6a and b). In its current condition, channel incision varies. Incision is typically highest downstream of knickpoints created by recently exposed bedrock ledges, and gradually lowers downstream until the next knickpoint. The West Branch of Rattlesnake Creek enters the reach at RM 1.7, contributing a substantial proportion of Rattlesnake Creek’s drainage area and discharge. Sediment and LWD at the mouth of the West Branch of Rattlesnake Creek has created a fish passage barrier, restricting access to relatively undisturbed habitat (Figure 6c and d). Near RM 1.75, a significant bedrock ledge and boulder pile is likely a fish passage barrier to upstream reaches on the mainstem of Rattlesnake Creek. Approximately 600 pieces of LWD are lodged on the toe of the hillslopes and valley bottom margin.

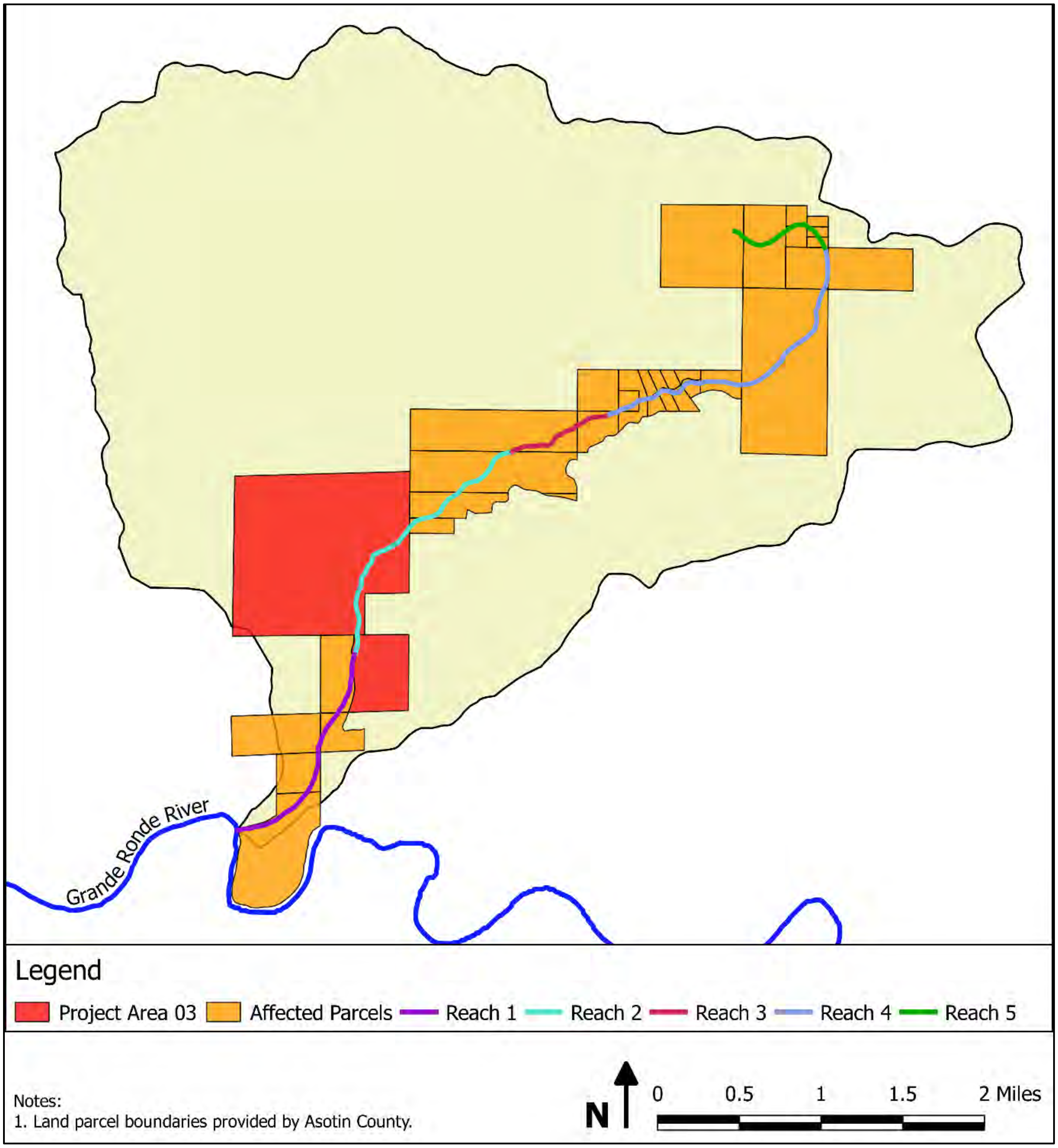

Figure 5. Location of Project Area 03 within the Rattlesnake Creek basin.

a. b. c. d.

Figure 6. Photos looking upstream (a) and downstream (b) on the mainstem of Rattlesnake Creek near the bottom of the project area and photos looking upstream (c) and downstream (d) of the barrier at the mouth of the West Branch of Rattlesnake Creek.

7.1.2 Conceptual Project Actions

Recommendations for PA-03 are to clear debris away from the mouth of the West Branch of Rattlesnake Creek to improve fish passage, use boulders to improve fish passage over the bedrock ledge at RM 1.75, move lodged LWD into the channel and floodplain, clean up trash debris between RM 1.5 and 1.7, riparian plantings near RM 2.05 and where feasible, and invasive vegetation control.

7.1.2.1 Geomorphic Implications

Removing the sediment and LWD from the mouth of the West Branch of Rattlesnake Creek will restore the fluvial geomorphic processes at the confluence, as it likely does not have the competence to move the material naturally.

Boulder placement at the bedrock ledge at RM 1.75 would reduce the local gradient and collect sediment like small check dams. Over time, this will resemble a cascade rather than a step.

The addition of LWD in the channel will reduce water and sediment transport times, connect the channel to the floodplain during high flow events, and increase hydraulic and geomorphic diversity in the form of critical habitat features (e.g., pools, bars, refuge, spawning gravel). Adding LWD to the floodplain will encourage the recovery of the riparian area by promoting fine sediment deposition and topsoil accumulation for future recruitment of native woody species and create planting opportunities.

7.1.2.2 Biological Benefits

Aside from the barrier at the mouth, the West Branch of Rattlesnake Creek was not affected during the flood; therefore, it will likely provide important refuge habitat while the mainstem recovers. Removing the barrier should be considered immediately as it will allow juveniles and adults to migrate to and from the major tributary.

The bedrock ledge at RM 1.75 is a significant fish passage barrier that cuts off several miles of critical habitat for fish. Even in their current condition, the reaches upstream of the ledge have spawning and rearing potential.

Adding LWD to the channel will encourage sediment retention, creating more spawning areas, and promote local scour in plane bed sections to increase pool frequency. LWD will also provide immediate predator and high flow refuge for juvenile salmonids. During high flows, LWD will force water onto the floodplain, creating off-channel habitat, provide high flow refuge, and promote natural sediment flux at a local scale. LWD placed on the floodplain will increase fine sediment deposition, helping to kickstart riparian and floodplain recovery. Only one potential area was identified for immediate riparian planting during the assessment, so LWD should be placed to protect this rare floodplain pocket to encourage the establishment and persistence of native riparian vegetation.

7.1.2.3 Potential Challenges

Heavy equipment will be able to access the channel and floodplain until the bedrock ledge at RM 1.75. Upstream of the ledge, access is limited to foot traffic. The project will require landowner acceptance.

7.2 Project Area 04 (RM 2.4 to 3.3)

7.2.1 Site Description

Project Area 04 (PA-04) is located from RM 2.4 to an unnamed tributary at RM 3.3 (Figure 7). The channel is characterized as partly confined, low sinuosity, dominated by runs and rapids separated by bedrock ledges. Geomorphic impacts from the flood are glaringly evident. Whereas downstream reaches were clearly impacted, resulting in the loss of riparian vegetation and topsoil, removal of LWD, and segments of rapid incision; the channel in PA-04 and the reaches upstream is also heavily impounded by excessive sediment (Figure 8a). Large boulder/cobble berms and sheets cover the entire valley bottom, and the main channel is not well-defined. Substrate in the valley bottom is loose and composed mostly of large size classes, allowing the creek to go subsurface for relatively short segments. A small unnamed tributary on river left is cut off from the mainstem, and marks the top of PA-04 (Figure 8b). There are approximately 50 pieces of lodged LWD along the valley margin.

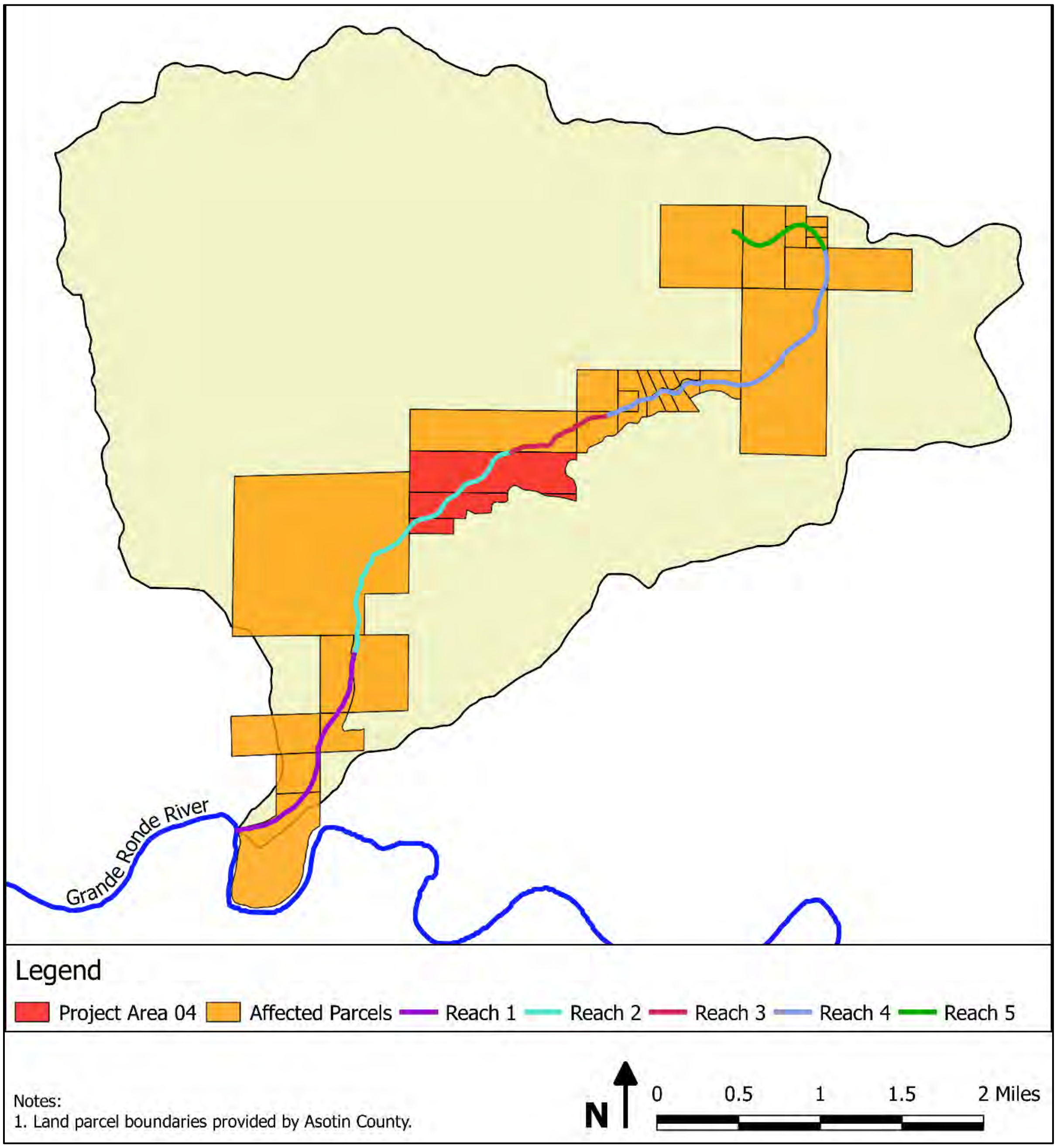

Figure 7. Location of Project Area 04 within the Rattlesnake Creek basin.

a. b.

Figure 8. Representative photo of PA-04 looking downstream showing excessive sediment impacting the channel (a), and the disconnected river left tributary near the top of the project area (b).

7.2.2 Conceptual Project Actions

The recommendations for PA-04 are to move lodged LWD into the channel and floodplain, move large boulders into the channel, reconnect the unnamed tributary at RM 3.3, riparian plantings, invasive vegetation control, and monitor geomorphic and habitat changes following subsequent high flow events.

7.2.2.1 Geomorphic Implications

Adding LWD and large boulders to the channel will reduce water and sediment transport time and increase hydraulic and geomorphic diversity. Without structural elements, it is likely that the channel will remain in its current condition until the next catastrophic high flow event or will rapidly cut down to bedrock. LWD and boulders locally increase stream competence by creating pinch points, allowing the channel to rework excessive sediment and recreate a naturally-consistent planform.

LWD and boulders placed in the channel should work in concert with those placed in the floodplain to allow ample opportunities for the channel to work sediment throughout the valley bottom and define a new channel and floodplain, fully sustainable under natural boundary conditions.

7.2.2.2 Biological Benefits

LWD and boulders placed in the channel will promote hydraulic diversity, improving instream habitat conditions for salmonids. The addition of LWD will provide high-flow refuge and low-flow cover for juvenile salmonids and will increase sediment retention, creating more spawning opportunities for adult salmonids. Local erosion forced by LWD and boulders will create and maintain pool habitats critical for juveniles. Ultimately, the increase in habitat diversity will lead to an increase in the carrying capacity of juvenile salmonids.

Increasing channel and floodplain interaction will help kickstart the recovery of the floodplain and riparian vegetation. Locally increasing stream competence will promote the recreation of a stream channel that is naturally sustainable under current boundary conditions, providing relatively stable habitat for rearing juvenile salmonids.

7.2.2.3 Potential Challenges

There is no access for heavy equipment to enter PA-04. There is very little LWD available on-site, so material would have to be brought in or cut directly from the adjacent hillslopes. The process of attaining trees directly from adjacent hillslopes will need to be completed using sustainable forestry practices without exacerbating negative impacts to the riparian area (e.g., SLLOPPS; Strong and Bevis, 2016).

The valley bottom in PA-04 will be sensitive to future disturbances and should be monitored following high flow events to determine its stability. High flow events may greatly alter the bed characteristics and channel planform in PA-04; therefore, an additional assessment should be conducted prior to working in this reach.

The project would require landowner acceptance.

8 REACH 3 CONCEPTUAL PROJECTS

Reach 3 is located from RM 3.30 at the confluence with an unnamed tributary on river left and extends 0.71 miles upstream, ending near RM 4.0. The reach is located entirely within private lands. At the bottom of the reach is a rib of massive bedrock chunks forming a complete fish passage barrier (Figure 10a). The channel is mostly undefined, smothered by excessive sediment composed mostly of boulders, and goes subsurface for long sections (Figure 10b and c). Reach 3 is the steepest of the delineated rehabilitation reaches with an average gradient of 11.8%. The top of Reach 3 also marks the upper extent of USFWS-designated critical habitat for steelhead. Approximately 75 pieces of LWD are lodged along the valley margin, most of which is racked into a single jam in the middle of the reach (Figure 10d).

There is a primitive access road on river left from Highway 129 to enter this reach. A private primitive road begins upstream of Reach 3 and follows the creek on river right; however, a section of the road from RM 3.75 to 3.9 was completely removed by the flood.

8.1 Project Area 05 (RM 3.3 to 4.0)

8.1.1 Site Description

The channel in Project Area 05 (PA-05) is a steep, single-thread, channel dominated by plane bed morphology (Figure 9). There are several sections of low-gradient runs; however, steps, cascades, and rapids skew the overall gradient through the reach. Massive chunks of the bedrock wall fell into the channel creating a substantial vertical drop and fish passage barrier at the bottom of PA-05. A LWD jam racked onto a boulder sheet and live trees at RM 3.65 create a pitched channel, splitting the flow roughly 50/50. There is nearly a six-foot elevational difference between the split channels.

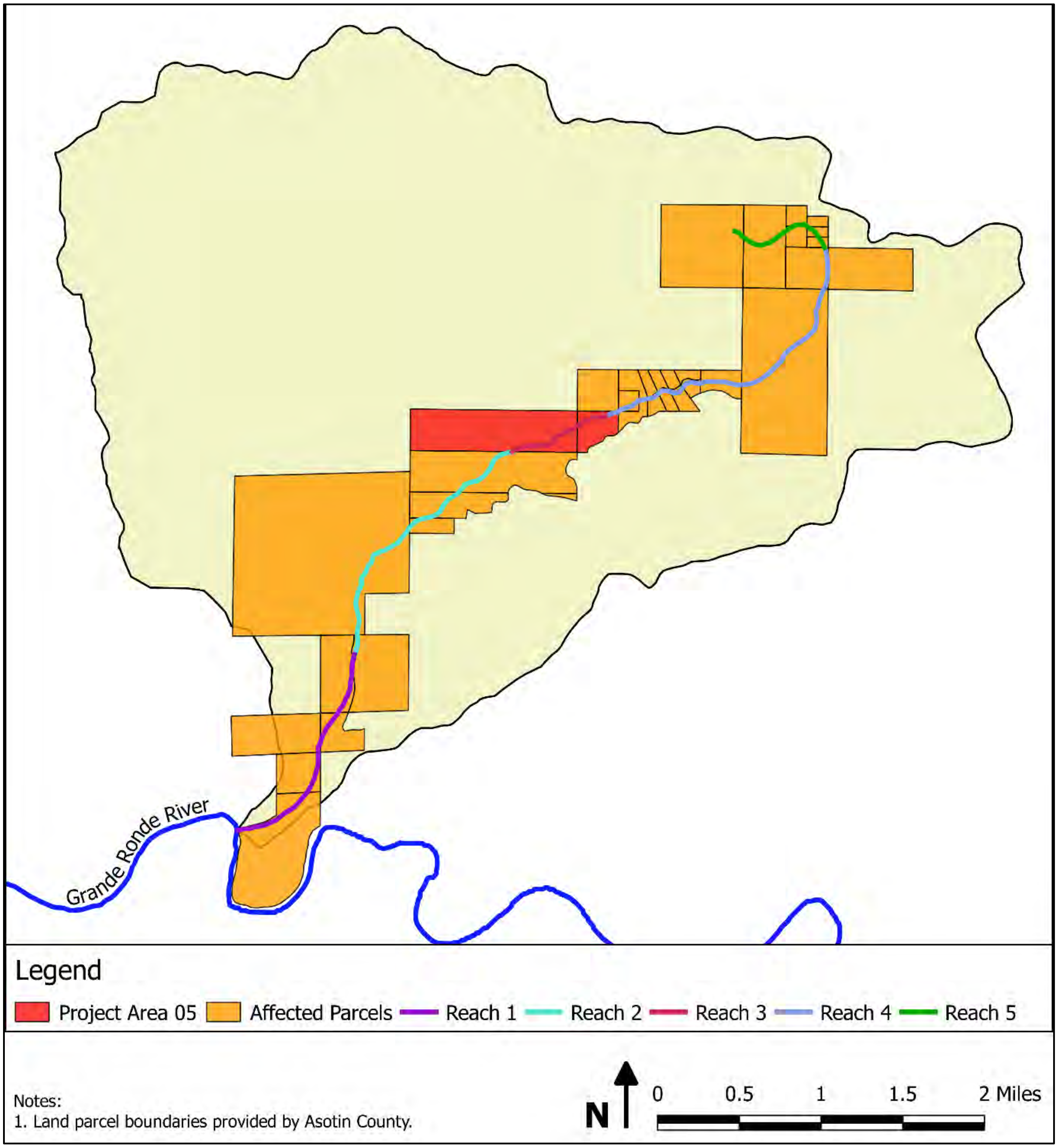

Figure 9. Location of Project Area 05 within the Rattlesnake Creek basin.

a.

b.

c.

d.

Figure 10. Photos of the complete fish passage barrier at the bottom of the reach (a), typical channel condition and habitat (b and c), and the massive large woody debris jam in the middle of the reach (d).

8.1.2 Conceptual Project Actions

Recommendations for PA-05 are to improve passage at RM 3.3, distribute LWD from the jam at RM 3.65 to the surrounding channel and floodplain, reorganize boulders throughout, riparian plantings where feasible, invasive vegetation control, and, if desired by the landowner, repair the private access road on river right from RM 3.75 to 3.9.

8.1.2.1 Geomorphic Implications

The chunks of bedrock creating the fish passage at the bottom of PA-05 are holding back a massive amount of sediment. Fully removing the barrier may promote head cutting into the loose substrate upstream; therefore, creating a cascade sequence using boulders and LWD would be a more sustainable option. The LWD jam in the middle of the reach is on top of a boulder sheet, ultimately held in place by a grove of large cottonwood trees. Pulling LWD pieces from the jam and distributing them to nearby channel and floodplain would improve hydraulic and geomorphic diversity at new placement sites. Reorganizing boulders from sheet deposits and placing them in the active channel will improve geomorphic and hydraulic complexity and sediment retention, helping to promote recovery.

The private access road on river right appears to have originally been cut into the hillslope, which would have had little impact on the confinement of the creek. Given the current condition of the channel and floodplain, reconstructing the road is not likely to delay recovery time within PA-05. The value of the road will have to be determined by the landowner. The feasibility of repairing the road is beyond the scope of this report.

8.1.2.2 Biological Benefits

Removing the barrier at RM 3.3 will provide access to the upper reaches of Rattlesnake Creek, including an additional 0.7 RM of critical habitat.

LWD placed throughout the channel and floodplain will provide immediate high-flow refuge and low-flow cover for juvenile salmonids. Over time, LWD will increase sediment retention, creating more suitable spawning areas for adult salmonids. LWD and boulders placed in the channel would also increase floodplain connection, helping to kickstart the recovery of riparian vegetation. LWD placed on the floodplain will promote fine sediment deposition, creating pockets of soil for the future recruitment of native riparian vegetation.

Reconstructing the road is not expected to have any biological benefits.

8.1.2.3 Potential Challenges

Despite the access road on river left and primitive road on river right, it will be very difficult to bring in heavy equipment. The barrier at the bottom of PA-05 may not be movable using small, packable equipment; however, boulders are plentiful and could potentially be used to create a cascade leading up to the barrier to improve passage.

There is not enough LWD on-site to sufficiently cover the project area. LWD could be hauled into the middle of PA-05, but would likely need to be carried by hand or using small, packable equipment into the channel. The project would require landowner acceptance.

9 REACH 4 CONCEPTUAL PROJECTS

Reach 4 is located from RM 4.0 and extends 2.1 miles upstream. Approximately 60% of the reach is within private lands, and 40% is within the boundary of Field Springs State Park. The bottom of Reach 4 also marks the upstream extent of critical habitat for Steelhead. Damage from the flood is arguably the most extensive within Reach 4. Flow regularly goes subsurface over long sections. A total of 13 subsurface segments were observed during the field assessment totaling 2803 feet (range = 40-388’, mean = 216’). In its current condition, it is not possible to characterize the stream channel within Reach 4. The channel transitions between flowing directly over bedrock with steep drops (Figure 11a and b) to a backlog of excessive sediment composed primarily of boulders and cobble where the creek goes subsurface (Figure 11c). Large boulder berms, some as tall as six feet, are frequent and separate the channel from the floodplain (Figure 11d). In some areas, the channel is deeply incised, dropping as much as seven feet, based on visible scour lines along the valley margin.

There is a gravel road that provides access to the upper portion of Reach 4, and a primitive road that follows the stream on river right. However, the access road on river right was heavily damaged in multiple areas, ultimately disconnecting access to several properties in the lower portion of the reach.

a.

b.

c.

d.

Figure 11. Photos exhibiting the current condition of Reach 4 on Rattlesnake Creek. Bedrock drops (a and b) and large boulder berms (d) are frequent, and the creek goes subsurface over long segments (c).

9.1 Project Area 06 (RM 4.0 to 5.0)

9.1.1 Site Description

Project Area 06 (PA-06) begins at the upstream extent of designated critical habitat for steelhead and extends one mile upstream through several private parcels, ending at the boundary of Field Springs State Park (Figure 12). The channel and floodplain were heavily modified by the flood, and are currently very active and unstable. There are frequent steep drops in elevation (Figure 13a), tall boulder berms that impose increased confinement on the creek, and excessive sediment composed mostly of boulders and large cobble where the creek goes subsurface (Figure 13b). The creek will require multiple high flow events to define a new, sustainable channel and develop a new floodplain.

There are approximately 90 pieces of LWD lodged along the valley margin. A primitive access road on river right was destroyed between RM 4.2 and 4.3, restricting access to several private parcels near the downstream end of PA-06.

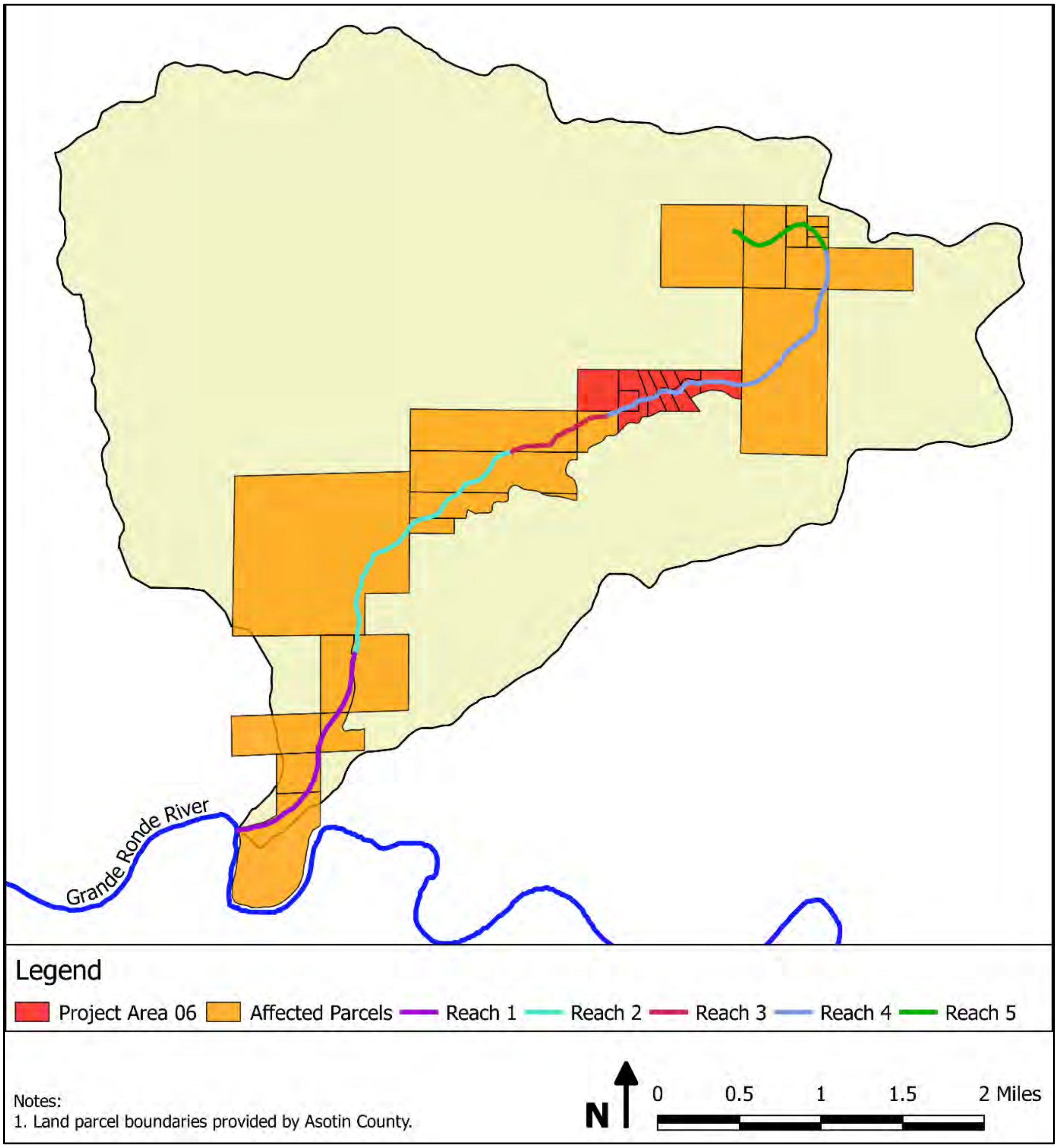

Figure 12. Location of Project Area 06 within the Rattlesnake Creek basin.

a. b.

Figure 13. Photos looking downstream towards a 20 foot drop in elevation with steep, exposed cut banks (a), and looking upstream along a large boulder berm and excessive sediment where the stream is subsurface (b).

9.1.2 Conceptual Project Actions

Recommendations for PA-06 are to allow 2-3 years for the creek to rework sediment in the valley bottom and define a new channel, move LWD lodged along the valley margin to the channel and floodplain, reorganize boulders to locally increase stream competence in opportunistic areas, repair/reconnect the access road on river right from RM 4.2 to 4.3, riparian plantings where feasible, and invasive vegetation control. Whether or not early projects are implemented in PA-06, habitat conditions including morphology and sediment characteristics of the channel and floodplain should be closely monitored.

9.1.2.1 Geomorphic Implications

The creek in PA-06 is highly active and unstable. It will require time and multiple high flow events to rework the recently deposited sediment and define a new channel. Adding LWD and reorganizing boulders to opportunistic locations in the present channel and valley bottom will help kickstart recovery of fluvial processes. However, early work in PA-06 should be completed at a small scale to determine its effectiveness. Recovery will be dependent on the magnitude of future high flow events and available sediment delivery from upstream reaches. Because PA-06 is located high in the watershed, high flow events and sediment delivery are expected to be low. Therefore, opportunistic positioning of structural elements within the channel will increase stream competence locally, aiding the development of a new channel.

It is possible that subsequent high flow events will cause more incision or head cutting, greatly increasing sediment delivery to downstream reaches. LWD and boulders will promote sediment retention in the confined areas and targeted erosion in the unconfined areas, hopefully resulting in a pseudo-equilibrium sediment flux while improving channel morphology.

Repairing and reconnecting the access road on river right may be a priority for local landowners, as it appears to be the only way to access several parcels within and downstream of PA-06. Determining the feasibility of repairing the road is beyond the scope of this report.

9.1.2.2 Biological Benefits
Reducing negative downstream effects is the primary biological benefit of the recommendations for PA-06. In its current state, fish capacity is likely very low, and there is very little potential for riparian vegetation to establish. However, because the stream bed and valley bottom are unstable, future high flow events will likely flush more sediment downstream. PA-06 should be monitored over time to identify opportunities for riparian planting projects to help kickstart recovery.

There are several fish barriers caused by steep bedrock drops, large boulder berms spanning the valley bottom, and long segments of subsurface flow. Over time, with adequate structural elements in place, fish passage will improve. Steelhead have been observed in neighboring watersheds (e.g., Charley Creek) upstream of the critical habitat boundaries, so it is likely that they were present in PA-06 prior to the flood.

9.1.2.3 Potential Challenges
Access to PA-06 is very limited. Heavy equipment will likely not be able to gain access to complete the work. Compared to downstream reaches, there is little LWD available onsite; however, the hillslope on river left could be thinned. Responsible thinning of the adjacent hillslope would improve forest health, reduce fire risk, and the material could be placed directly into the channel.

The project will require landowner acceptance.

9.2 Project Area 07 (RM 5.0 to 5.8)

9.2.1 Site Description
Project Area 07 (PA-07) is located entirely within the boundary of Field Springs State Park (Figure 14). The channel and floodplain were heavily modified by the flood, and are currently active and unstable. There are less bedrock drops than PA-06, but the gradient has likely increased following the flood because the channel is straight and deeply incised in many sections (Figure 15a and c). The valley bottom has been scoured down as much as eight feet, and all top soil and vegetation has been removed. A defined channel is often absent as flow goes subsurface through massive debris flow deposits. There is evidence of multiple debris flow episodes as indicated by scour lines at multiple elevations and distinct vertical layers of recent deposits of well-sorted substrate classes (e.g., boulder berms atop gravel sheets; Figure 15b and d). There are approximately 40 pieces of LWD lodged along the valley margin.

A private access road follows the creek on river right and was damaged in some areas. For example, the road between RM 5.5 and 5.6 is partially intact, but the creek is currently flowing against the toe of a vertical cut bank supporting the road prism. It is likely that future high flows will continue to threaten the integrity of the road at this location and others like it throughout PA-07 and in downstream reaches. This road is the only access to several private parcels downstream.

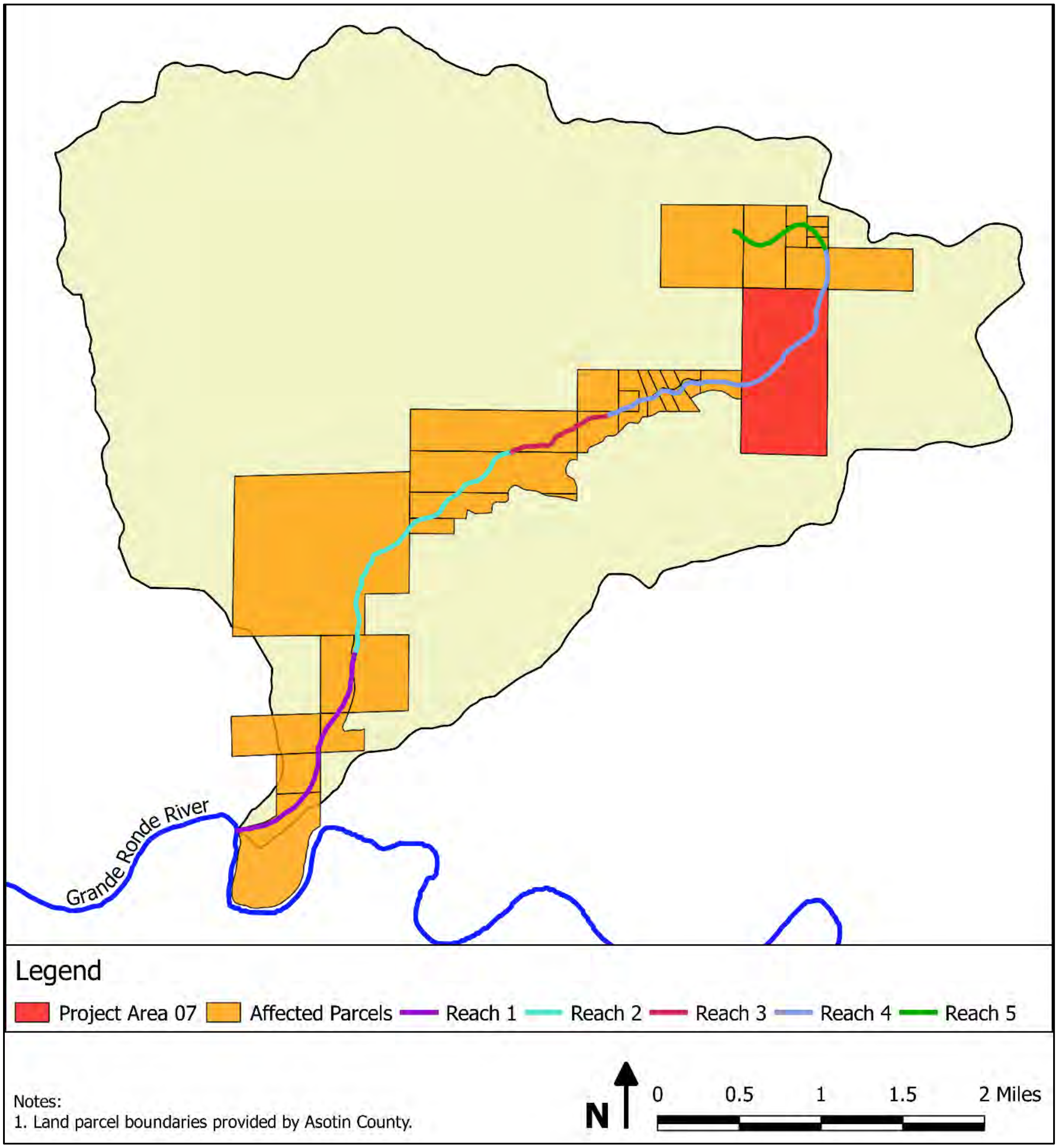

Figure 14. Location of Project Area 07 within the Rattlesnake Creek basin.

Figure 15. Photos looking downstream at the deeply incised channel near the top of Project Area 07 (a), a massive boulder deposit atop a gravel sheet (b), looking downstream of the incised valley bottom and channel (c), and looking upstream at multiple distinct scour lines and sorted deposits (d).

9.2.2 Conceptual Project Actions

Recommendations for PA-07 are to allow 2-3 years for the creek to rework sediment in the valley bottom and define a new channel, move lodged LWD from valley margin to channel and floodplain, reorganize boulders to locally increase stream competence and retain sediment in the floodplain, lower the height of the boulder berms and distribute material throughout the valley bottom, repair the private access road from RM 5.5 to 5.6, riparian plantings where feasible, and invasive vegetation control.

9.2.2.1 Geomorphic Implications

The valley bottom in PA-07 is active and highly unstable. It will require several high flow events to rework the debris flow deposits and define a new channel in some areas. Depending on available sediment sources upstream and the magnitude of future high flow events, it may take several decades for the creek to naturally recover.

Adding LWD and organizing boulders within incised sections will promote sediment retention to reduce the rate of incision, and over time aggrade the channel. Several boulder berms will behave similar to levees by increasing channel confinement and encouraging incision. Removing the berms, or distributing the material throughout the valley bottom will promote lateral migration when completed in conjunction additional structural elements.

LWD and boulders placed within the floodplain will promote the retention of fine sediment during high flow events and help promote the recovery of riparian vegetation.

The creek currently flows along the toe of the road prism on river right. Repairing the road would likely require a lot of resources and heavy channel and bank armoring; however, the negative impacts of such construction activities would be negligible given the current condition of the channel in PA-07.

9.2.2.2 Biological Benefits

Reducing negative downstream effects is the primary biological benefit of the recommendations for PA-07. In its current state, fish capacity is likely very low, and there is very little potential for riparian vegetation to establish. However, because the stream bed and valley bottom are unstable, future high flow events will likely flush more sediment downstream. Increasing the frequency of active LWD and boulders will promote sediment retention, especially if structures are placed to increase floodplain connection, dispersing flow and fine sediment laterally. PA-07 should be monitored over time to identify opportunities for riparian planting projects to help kickstart recovery.

9.2.2.3 Potential Challenges

There is a road to the top of PA-07 allowing access into PA-07; however, navigating downstream may be difficult and cause more disturbance to already unstable areas.

There is very little LWD available on-site to complete the recommended work. However, the hillslopes along PA-07 are densely forested, and appear to be dominated by relatively young conifers. It would be beneficial to selectively thin the hillslopes to improve forest health and reduce fire risk. Thinned material could be placed directly into valley bottom.

9.3 Project Area 08 (RM 5.8 to 6.1)

9.3.1 Site Description

Project Area 08 (PA-08) is located within private property, starting at the boundary of Field Springs State Park and extending upstream for only 0.3 miles, ending at a private road crossing (Figure 16). The channel and floodplain has been scoured down to bedrock in most areas (Figure 17a and b), until the upstream end of a head cut near RM 6.0 (Figure 17c). Upstream of the head cut, valley gradient decreases, confinement decreases, and channel character changes to a valleyfill meadow (e.g., Figure 17d). Because PA-08 is located high in the basin, there was not a thick layer of topsoil in the valley bottom before the flood, so even though bedrock is exposed in most areas, the overall depth of incision is not as severe as downstream reaches. Regardless of how much topsoil was present, the floodplain is damaged and riparian vegetation is mostly non-existent.

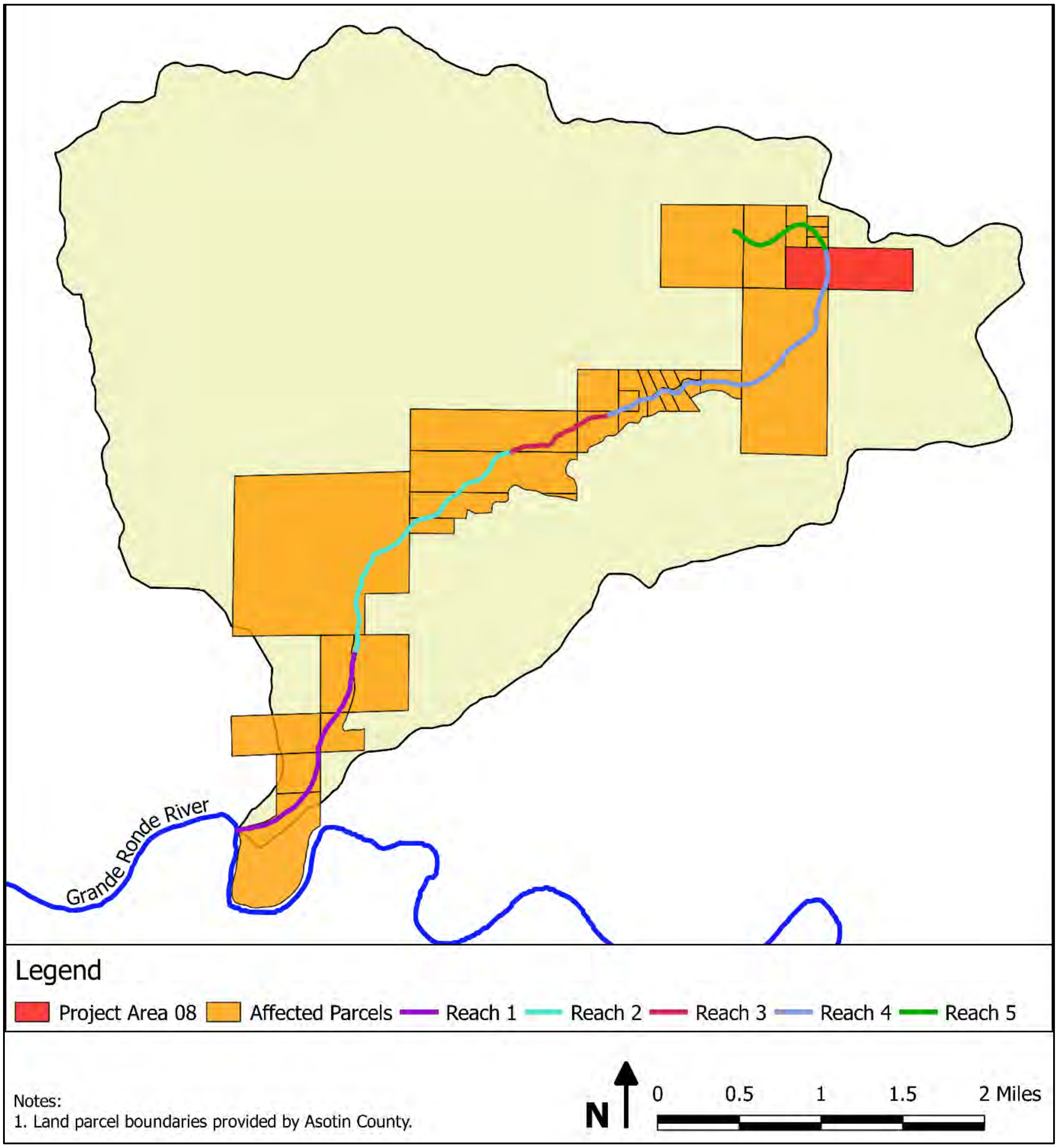

Figure 16. Location of Project Area 08 within the Rattlesnake Creek basin.

Figure 17. Photos looking downstream of incision down to bedrock (a and b), start of a head cut near RM 6.0 (c), and a low gradient meadow section near the top of PA-08 (d).

9.3.2 Conceptual Project Actions

Recommendations for PA-08 are riparian plantings, LWD additions, and invasive vegetation control.

9.3.2.1 Geomorphic Implications

Adding LWD throughout the channel and floodplain will promote sediment retention, helping to aggrade the valley bottom and retain topsoil. The head cut near RM 6.0 will likely continue migrating upstream into the meadow sections in PA-08 and upstream reaches. Stabilizing the head cut will help protect meadow areas that may be an important riparian vegetation seed source to downstream reaches in the future.

9.3.2.2 Biological Benefits

Riparian plantings focused near the meadow areas will provide an important native vegetation seed source to downstream reaches over time. LWD additions will increase floodplain connectivity and sediment retention, helping to accumulate topsoil and kickstart riparian recovery.

9.3.2.3 Potential Challenges

Access to PA-08 is limited, making it difficult to get heavy equipment into the project area to complete the recommended work.

This project will require landowner acceptance.

10 REACH 5 CONCEPTUAL PROJECTS

Reach 5 is located from RM 6.1 and extends to the top of the focus area at RM 6.8. A large hawthorn thicket that spans the valley bottom from RM 6.6 to 6.8. Damage to the channel and floodplain within this thicket is minimal, likely because the dense vegetation dissipated energy from the flood.

10.1 Project Area 09 (RM 6.1 to 6.8)

10.1.1 Site Description

Project Area 09 (PA-09) is the only project area in Reach 5 and is entirely within private lands (Figure 18). The gradient and valley confinement are variable throughout the reach, transitioning between steep confined sections, and unconfined meadows. A pond near RM 6.5 was damaged by the flood, but remains partially intact (Figure 19a). Downstream of the pond, the valley bottom is scoured down to bedrock (e.g., Figure 19b) in most areas until the channel reaches a private road crossing near RM 6.3. A large boulder sheet was deposited downstream of the road, extending downstream nearly 0.2 RM. Some work has already been done to repair damages from the flood including creating a small dike along the channel near RM 6.2 (Figure 19c). There are several private roads with access to the parcels affected by the flood. Two roads with culverts cross the channel and both were damaged, but have been fixed or replaced. The lower culvert is clogged with sediment and backing up water upstream of the road crossing (Figure 19d). Material in the culvert appears to be mostly fines, sands, and gravel, so it may clear itself during the next high flow event; however, if the sediment is not cleared, more damage could be caused to the road and downstream reaches.

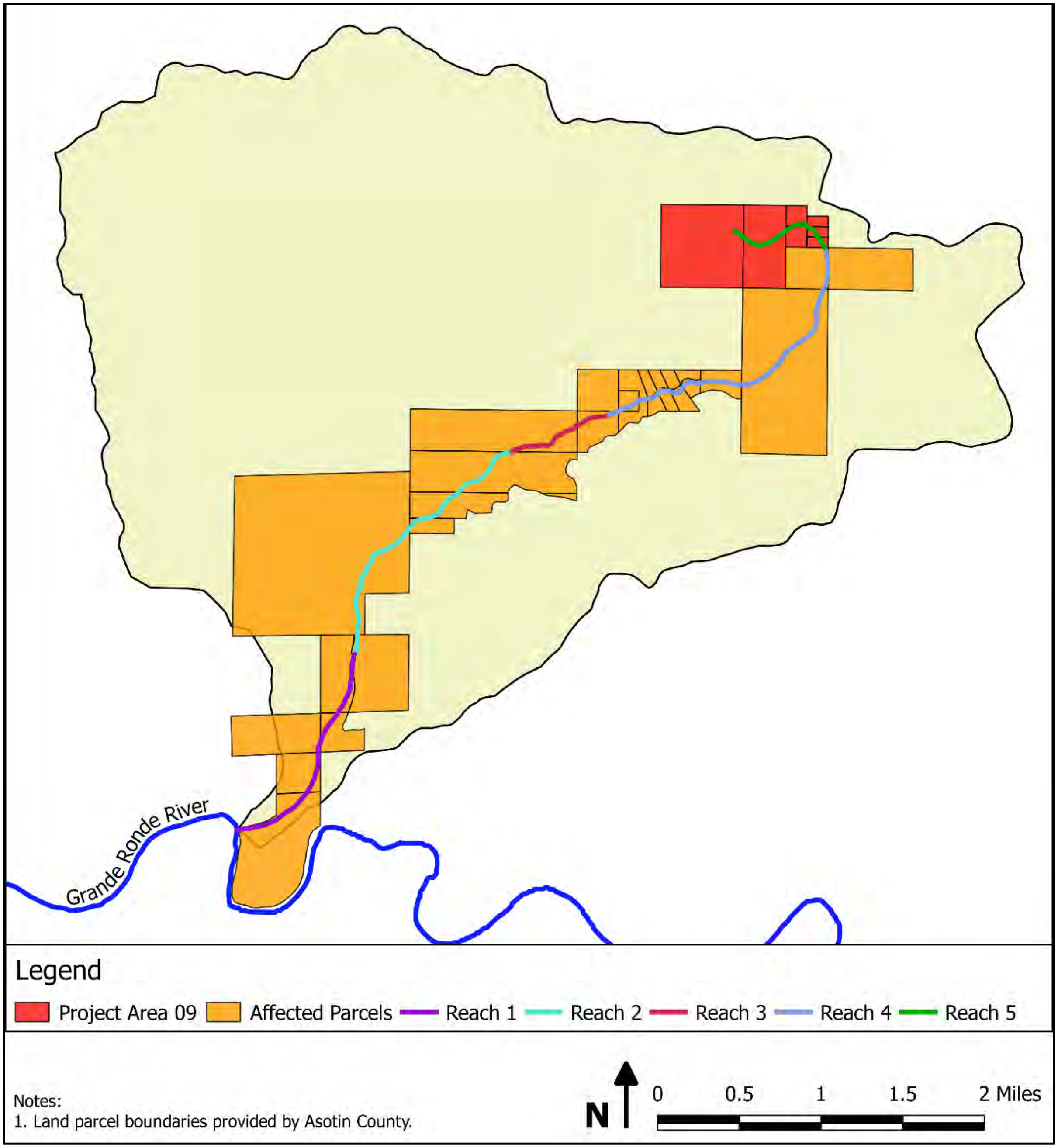

Figure 18. Location of Project Area 09 within the Rattlesnake Creek basin.

Figure 19. Pictures of PA-09 looking at damage at the lower pond (a), excessive erosion downstream of the pond (b), a small dike made from boulders deposited after the flood (c), and a clogged culvert backing up water upstream of a road crossing (d).

10.1.2 Conceptual Project Actions

Recommendations for PA-09 are to stabilize the lower pond to lower risk of a breach, riparian plantings, removing large rocks and boulders from selected areas, LWD additions throughout the channel and floodplain, and invasive vegetation control.

10.1.2.1 Geomorphic Implications

Stabilizing the pond will reduce the risk of future damage to the site and downstream reaches. Clearing or removing the large boulder sheet and small dike will improve floodplain connectivity and lateral channel migration in low-gradient areas. Maintaining the natural gradient and valley width variability within PA-09 will promote retention of sediment in pockets. LWD additions in the channel and floodplain will promote sediment retention to aggrade incised areas, and retain fine sediment on the floodplain to help kickstart riparian recovery.

10.1.2.2 Biological Benefits

Riparian plantings in the low-gradient sections with a wide and accessible floodplain would become an important native seed source for downstream reaches over time.

10.1.2.3 Potential Challenges

There is very little LWD available on-site to complete the proposed work; however, material from the boulder sheet could be used to off-set the amount of LWD required and achieve similar objectives. This project will require landowner acceptance.

11 SUMMARY OF PROJECT ACTIONS

The recommended projects actions in this report will improve hydraulic and geomorphic diversity, thereby improving and increasing critical habitat for ESA-listed salmonid species. In addition, the recommended actions target poorly functioning or disconnected geo-fluvial processes. The recommended actions are also expected to buffer negative impacts to water quality (e.g., reduce sedimentation). The extent of lost topsoil in the floodplain means there are currently very few opportunities where riparian plantings are expected to be successful (approximately 2.7 total acres). Riparian enhancement locations were identified based on current conditions, so the total area is restricted by the availability of suitable top soil. However, if other project actions are implemented over the next 1-3 years, floodplain conditions are expected to improve with increased channel to floodplain interaction, leading to more opportunities for riparian plantings. Soil amendments should be considered to increase opportunities for riparian planting in conjunction with the recommended project actions; however, an additional assessment should be completed to identify locations where soil is expected to be retained during high flow events. Despite limited topsoil, invasive vegetation was quick to colonize in all the project areas, so invasive vegetation control should be a priority in every reach. Monitoring of habitat and water quality parameters should be highly considered to inform future assessments, planning, and project implementation. Although project prioritization is beyond the scope of this report, the barrier at the mouth of the West Branch of Rattlesnake Creek should be addressed immediately. The primary recommended actions are summarized in Table 7.

Table 7. Summary of recommended project actions for project areas in the Rattlesnake Creek basin.

		River Mile		Project Actions (linear feet)				
Reach	Project Area	From	To	LWD Addition	Boulder Reorganization	LWD and Boulder Combination	Current Riparian Enhancemnt (acres)	Fish Barriers
1	**1**	0.00	0.50	1531	-	211	0.45	3
1	**2**	0.50	1.45	3221	1162	370	0.74	-
2	**3**	1.45	2.40	4382	-	422	0.26	2
2	**4**	2.40	3.30	686	3010	1162	-	-
3	**5**	3.30	4.00	1162	1214	-	-	2
4	**6**	4.00	5.00	1426	686	1954	-	5
4	**7**	5.00	5.80	2218	1690	264	0.17	-
4	**8**	5.80	6.10	-	-	1531	-	-
5	**9**	6.10	6.80	-	-	3538	1.08	-

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13 Basin Map Appendix

13.1 Elevation Map

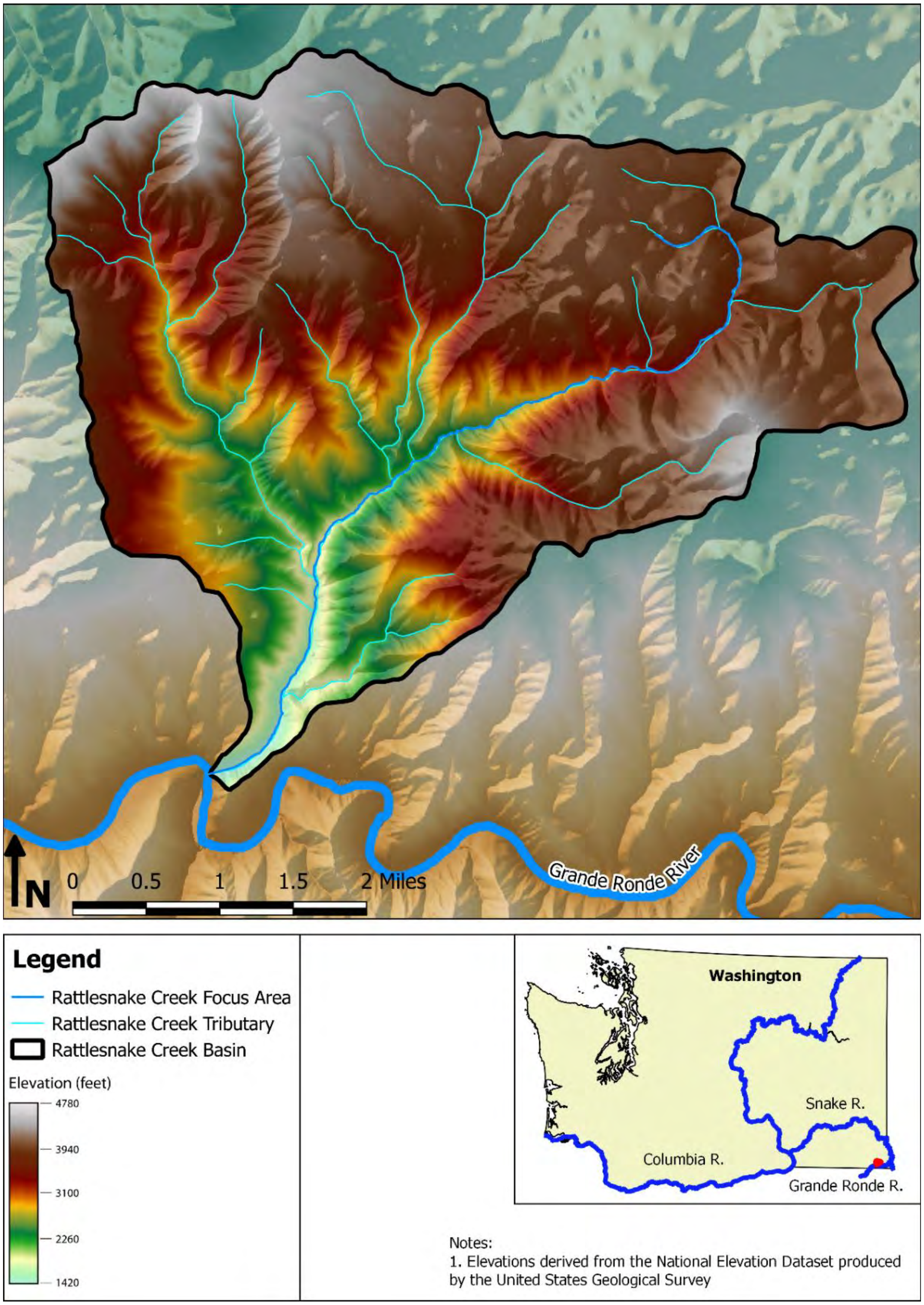


Figure 1. Elevation map of the Rattlesnake Creek basin derived from the United States Geological Survey National Elevation Dataset.

13.2 Geology Map

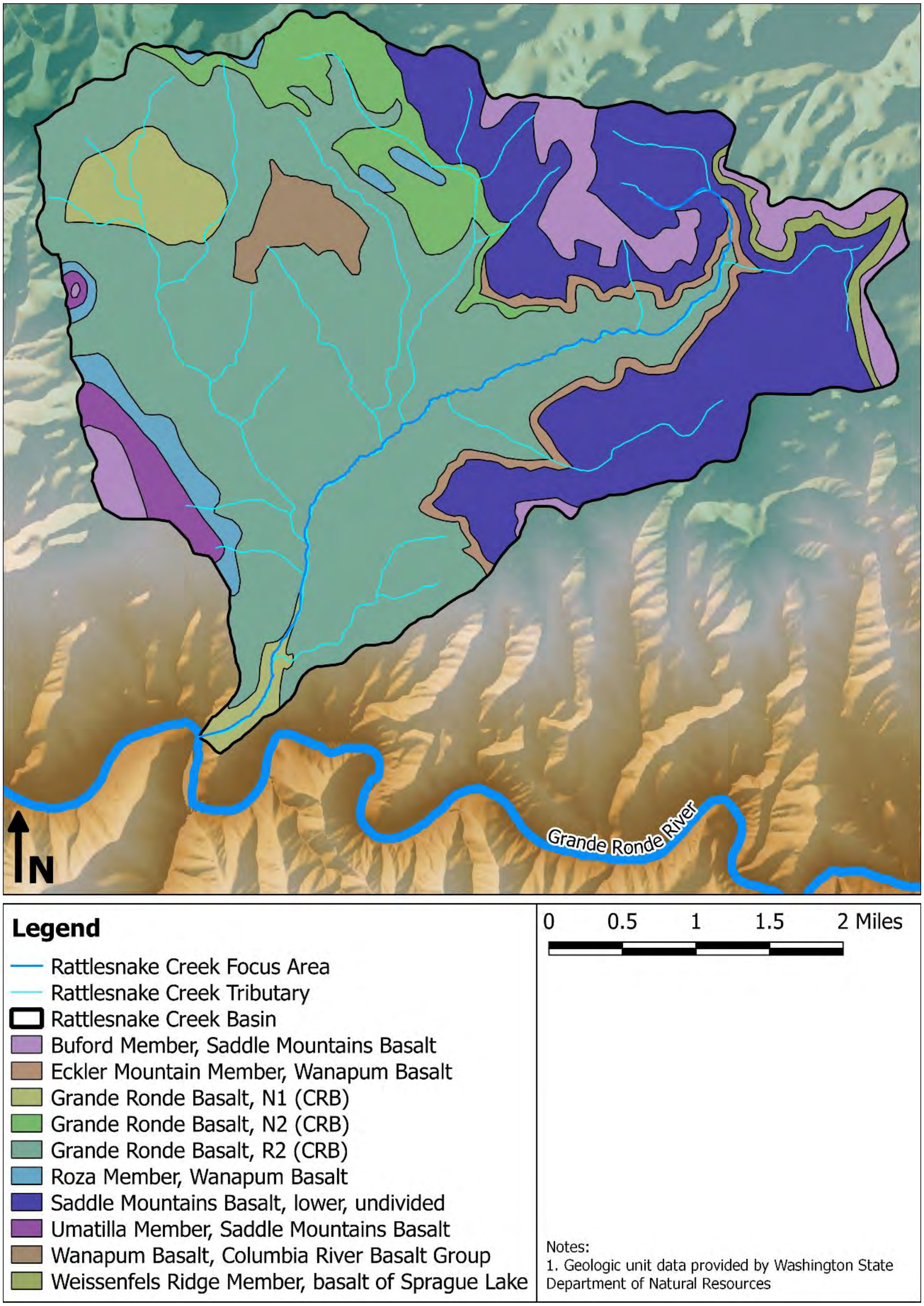


Figure 2. Map of surficial geologic units in the Rattlesnake Creek basin.

13.3 Soils Map

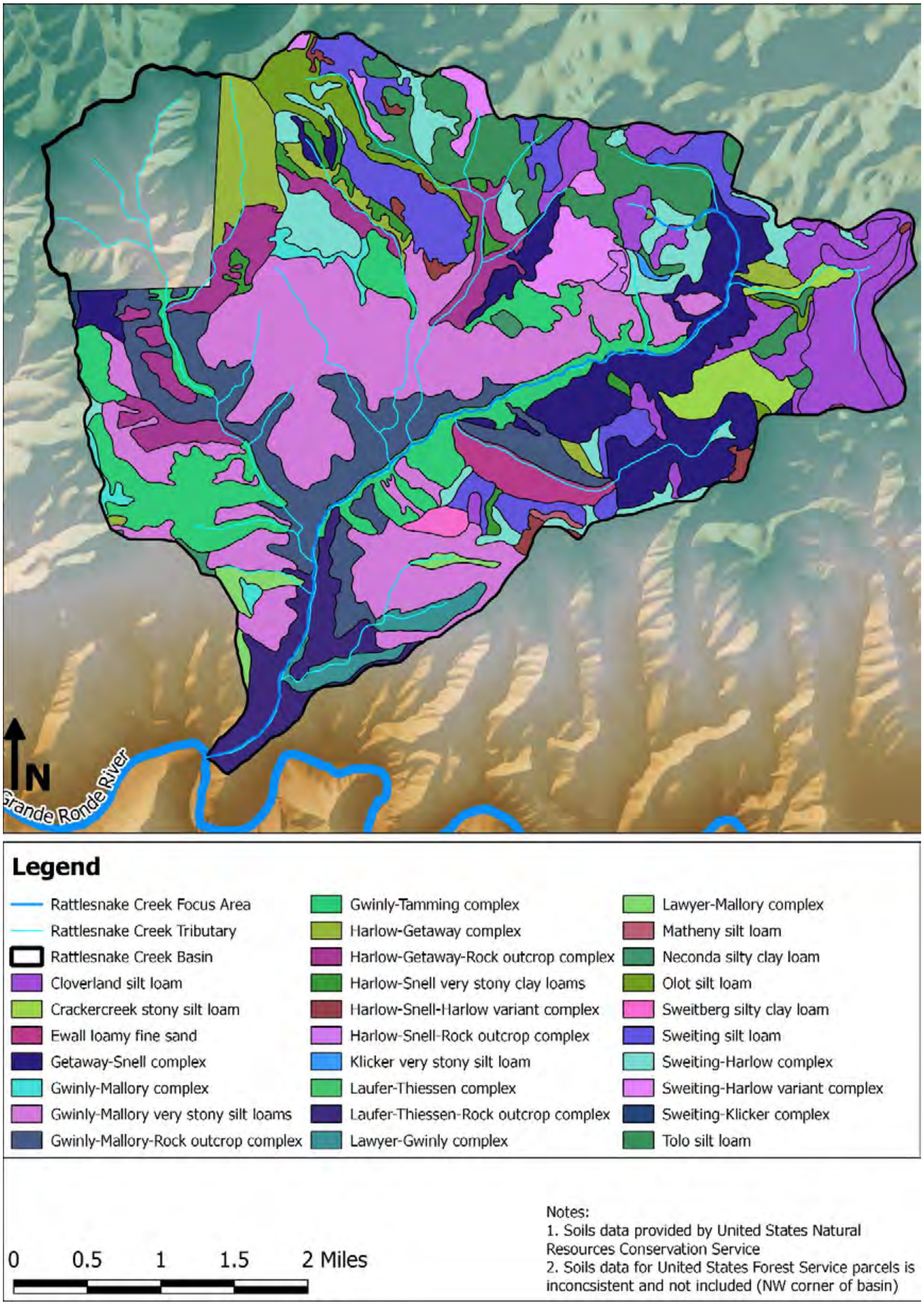


Figure 3. Map of dominant soil types in the Rattlesnake Creek basin derived from data provided by the United Sates Natural Resources Conservation Service.

13.4 Land Cover Map

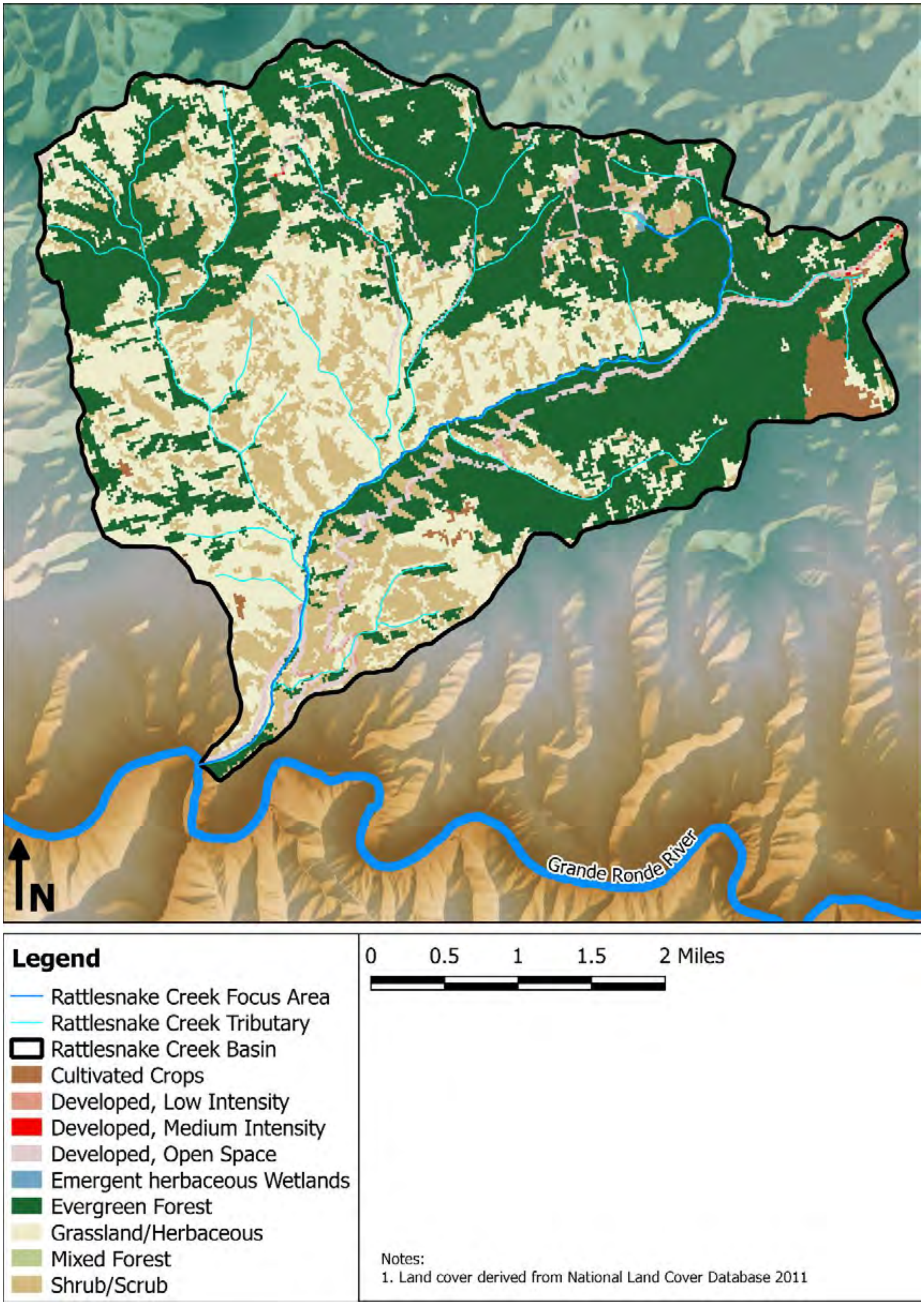


Figure 4. Land cover in the Rattlesnake Creek basin, derived from the National Land Cover Database (Homer et al., 2015).

13.5 Land Ownership Map

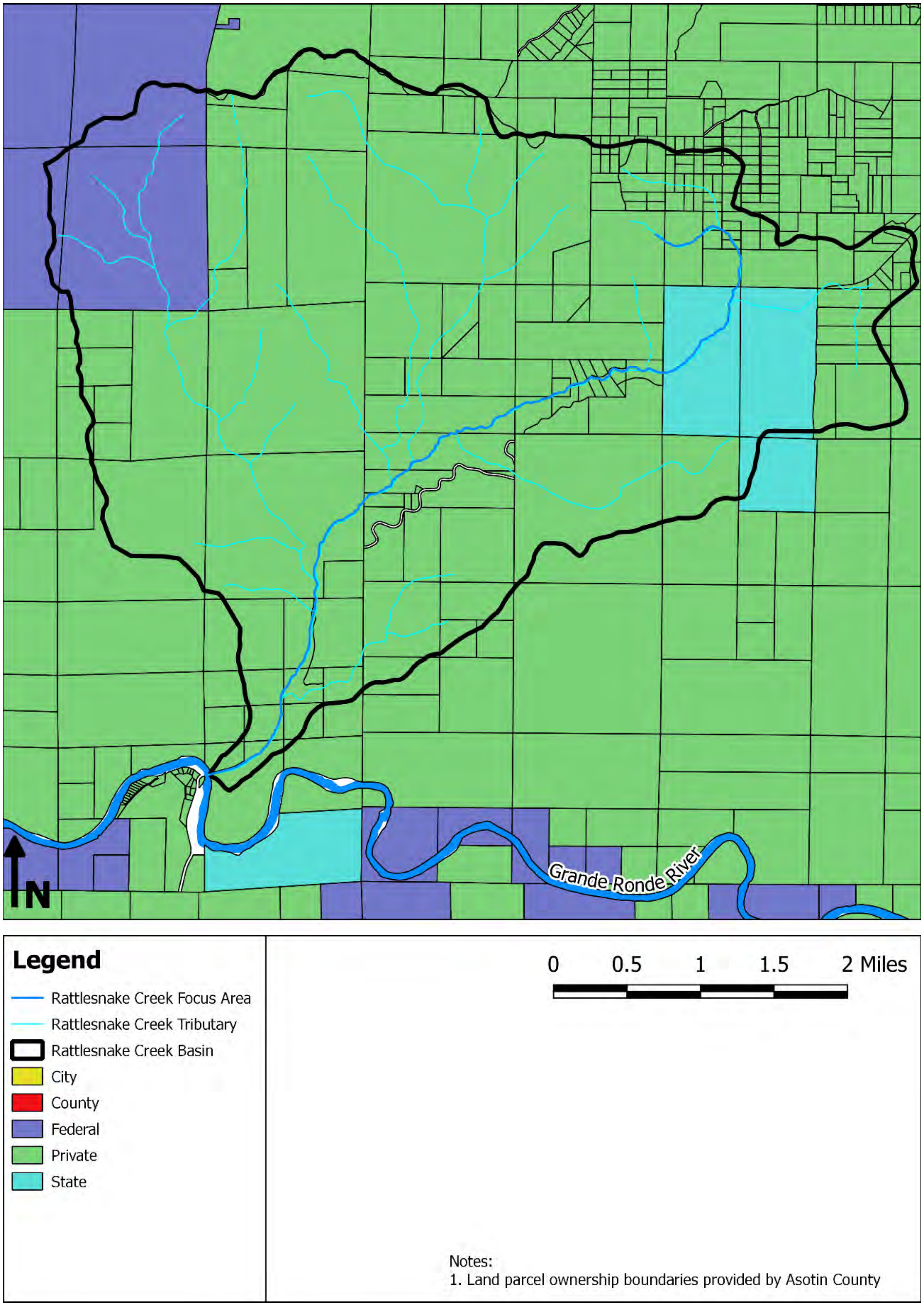
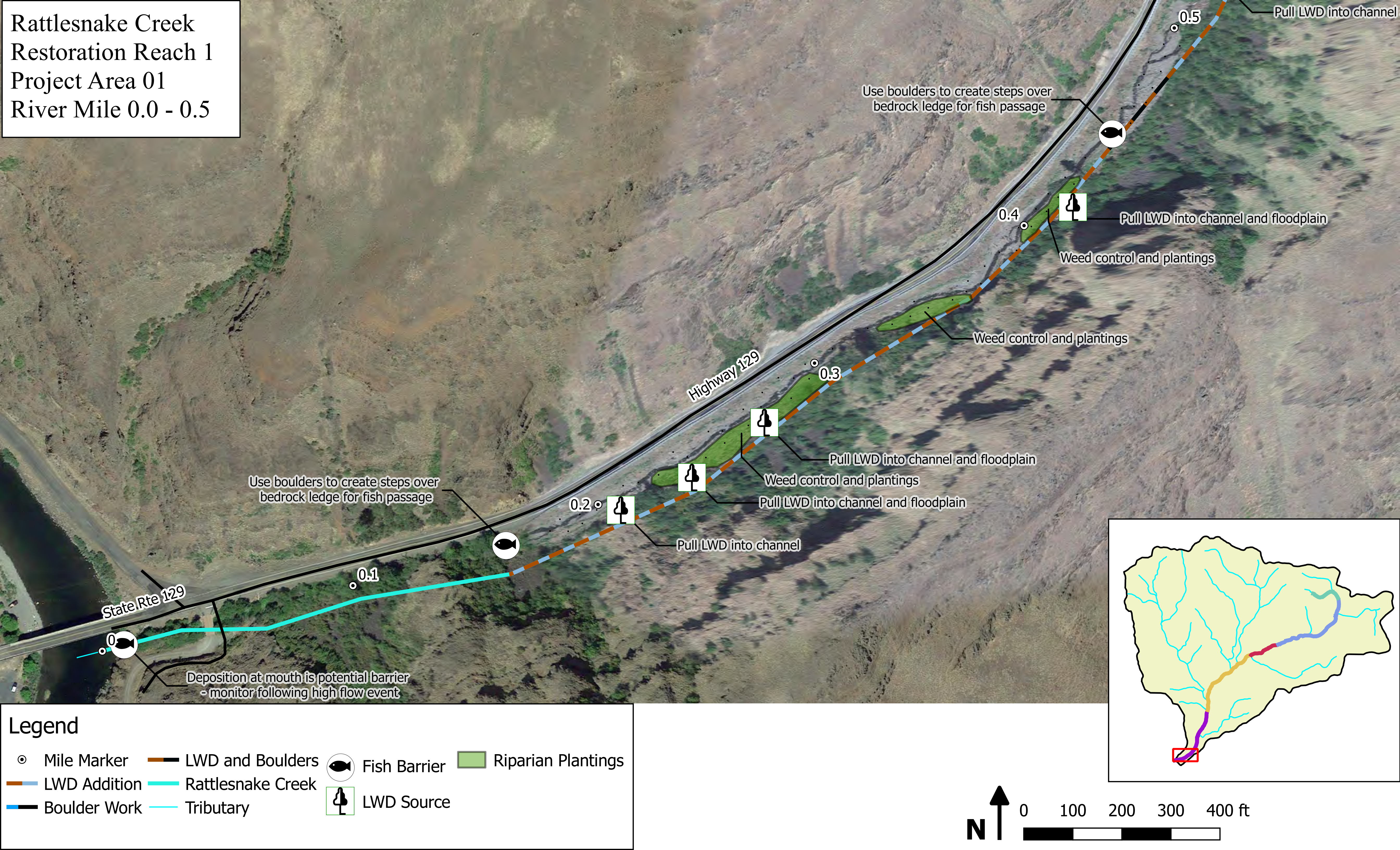


Figure 5. Land ownership by parcel in the Rattlesnake Creek basin and surrounding area.

14 Project Area Map Appendix

The following maps highlight the recommended project actions and opportunities discussed in the Rattlesnake Creek Conceptual Rehabilitation Plan for nine project areas identified in the basin. Maps are labeled by rehabilitation reach and project area, and organized from downstream to upstream. Each map labels the instream and floodplain recommendations, riparian planting opportunities, potential fish passage barriers, disconnected and damaged roads, local LWD sources, and other specific recommended actions discussed in the report.

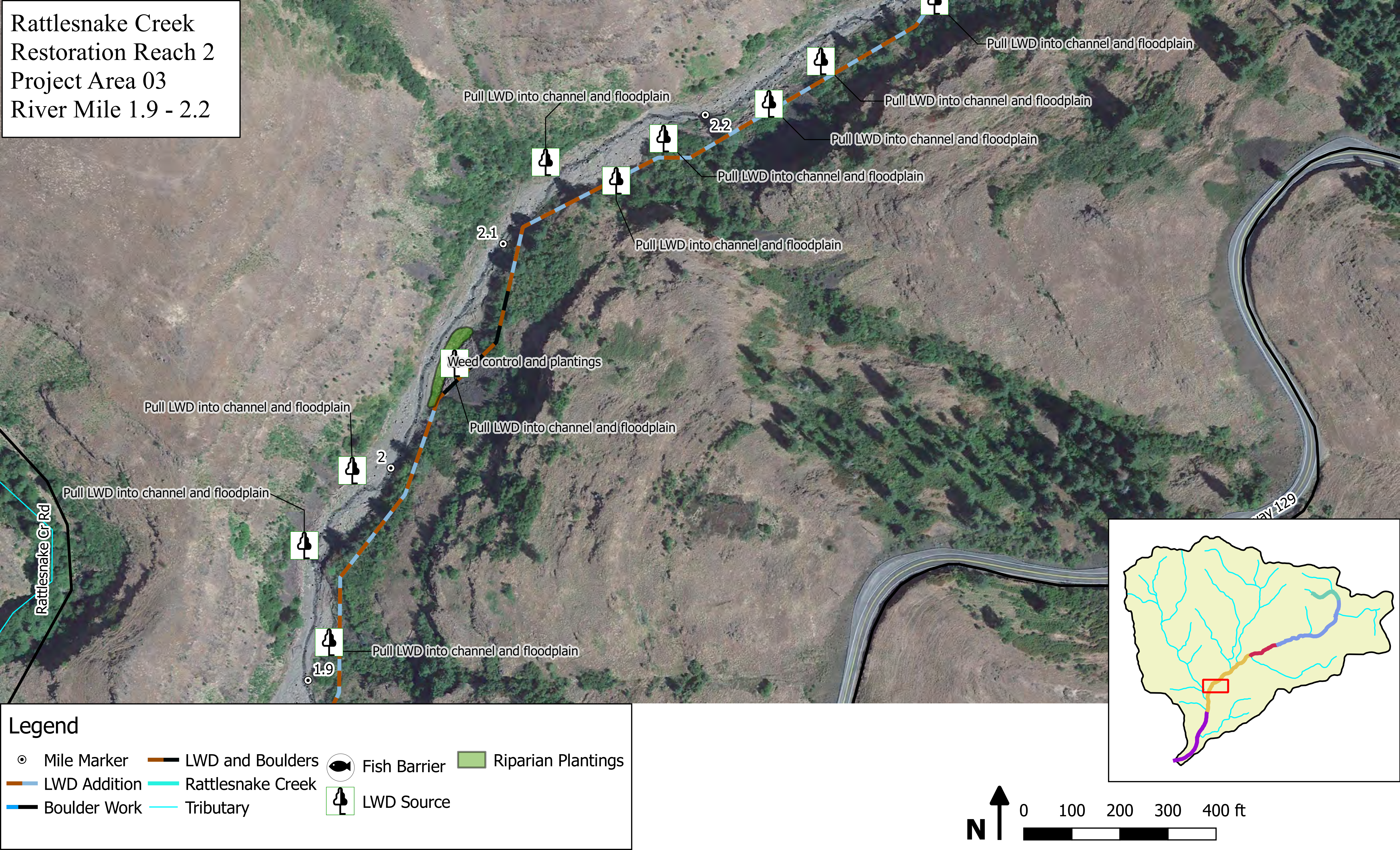
Rattlesnake Creek Restoration Reach 1 Project Area 01 River Mile 0.0 - 0.5

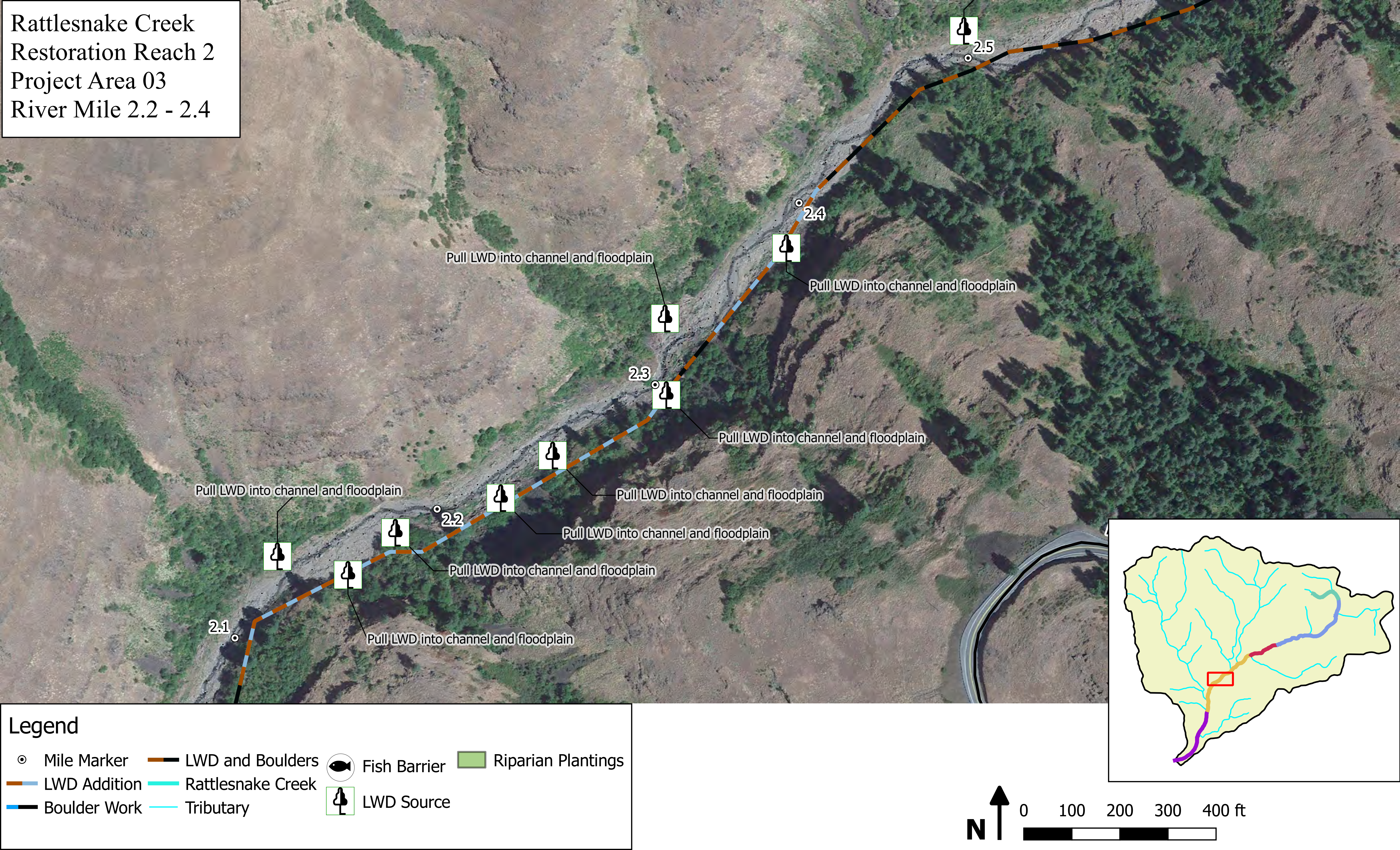


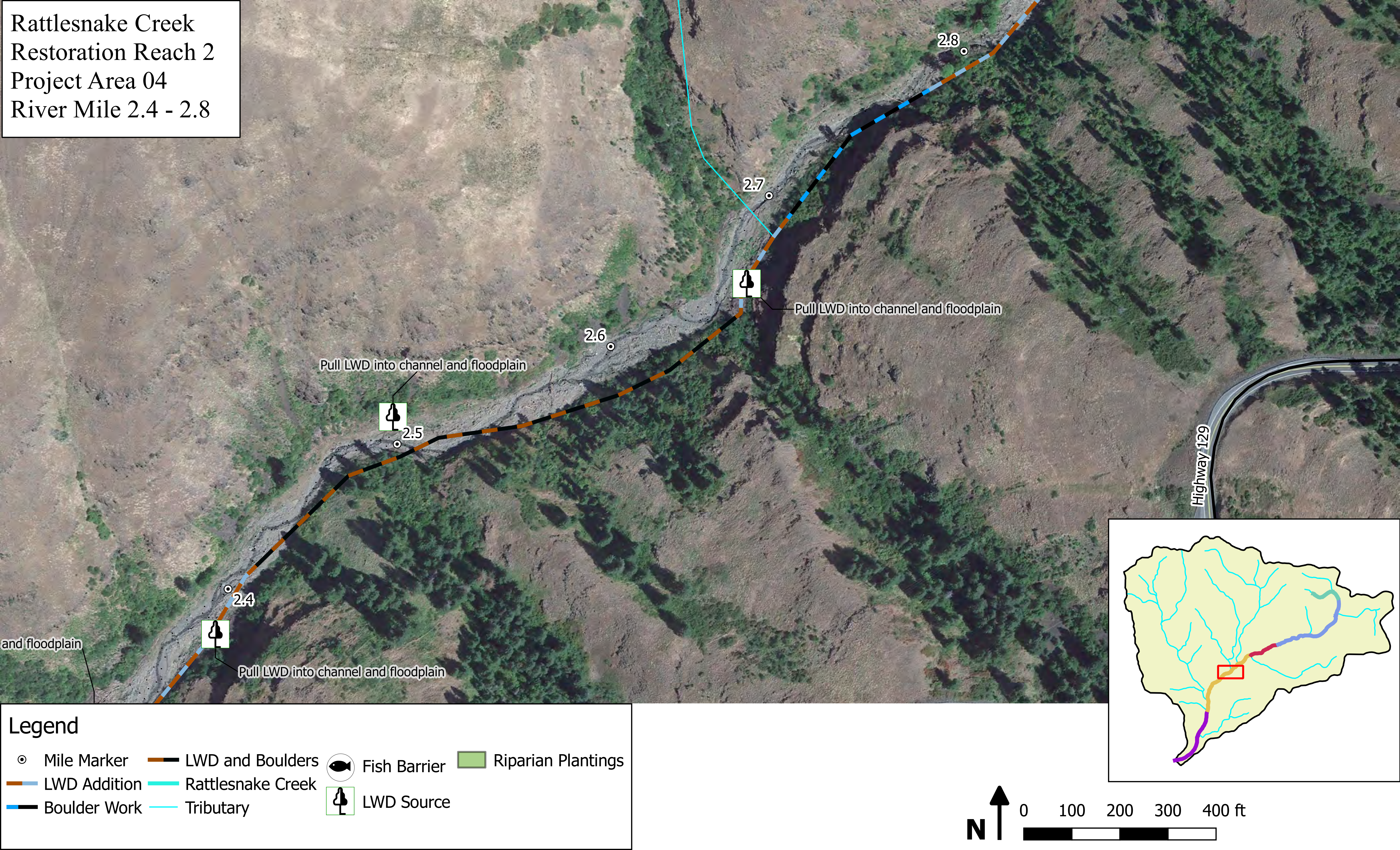
Rattlesnake Creek
Restoration Reach 1
Project Area 02
River Mile 0.5 - 1.0
Weed control and plantings
1
Pull LWD into channel and floodplain
Weed control and plantings
Pull LWD into channel and floodplain
0.9
Pull LWD into channel and floodplain
Weed control and plantings
Weed control and plantings
0.8
Highway 129
Pull LWD into channel and floodplain
0.7
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
0.6
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
0.5
Pull LWD into channel and floodplain
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
100
200
300 ft

Rattlesnake Creek
Restoration Reach 1
Project Area 02
River Mile 1.0 - 1.45

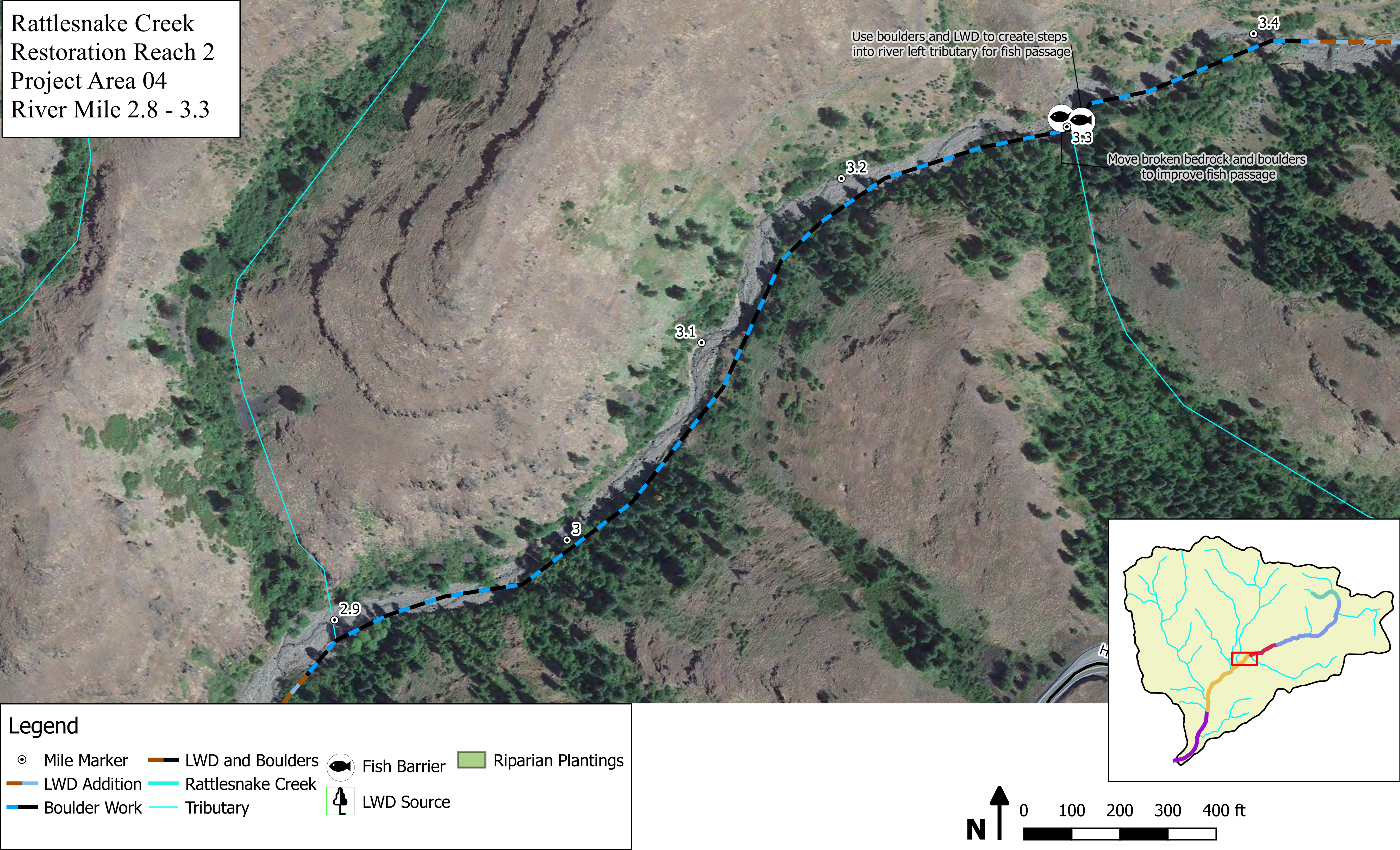

Rattlesnake Creek
Restoration Reach 2
Project Area 03
River Mile 1.45 - 1.9
Pull LWD into channel and floodplain
1.9
Pull LWD into channel and floodplain
Highway 129
1.8
Pull LWD into channel and floodplain
Use boulders to create steps over bedrock ledge for fish passage
Pull LWD into channel and floodplain
Remove LWD and racked material from mouth of West Fork
1.7
Pull LWD into channel and floodplain
Remove debris from site
Rattlesnake Cr Rd
1.6
Remove debris from site
Pull LWD into channel and floodplain
Weed control and plantings
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
1.5
Weed control and plantings
Protect bridge from sediment and debris overload
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
100
200
300 ft

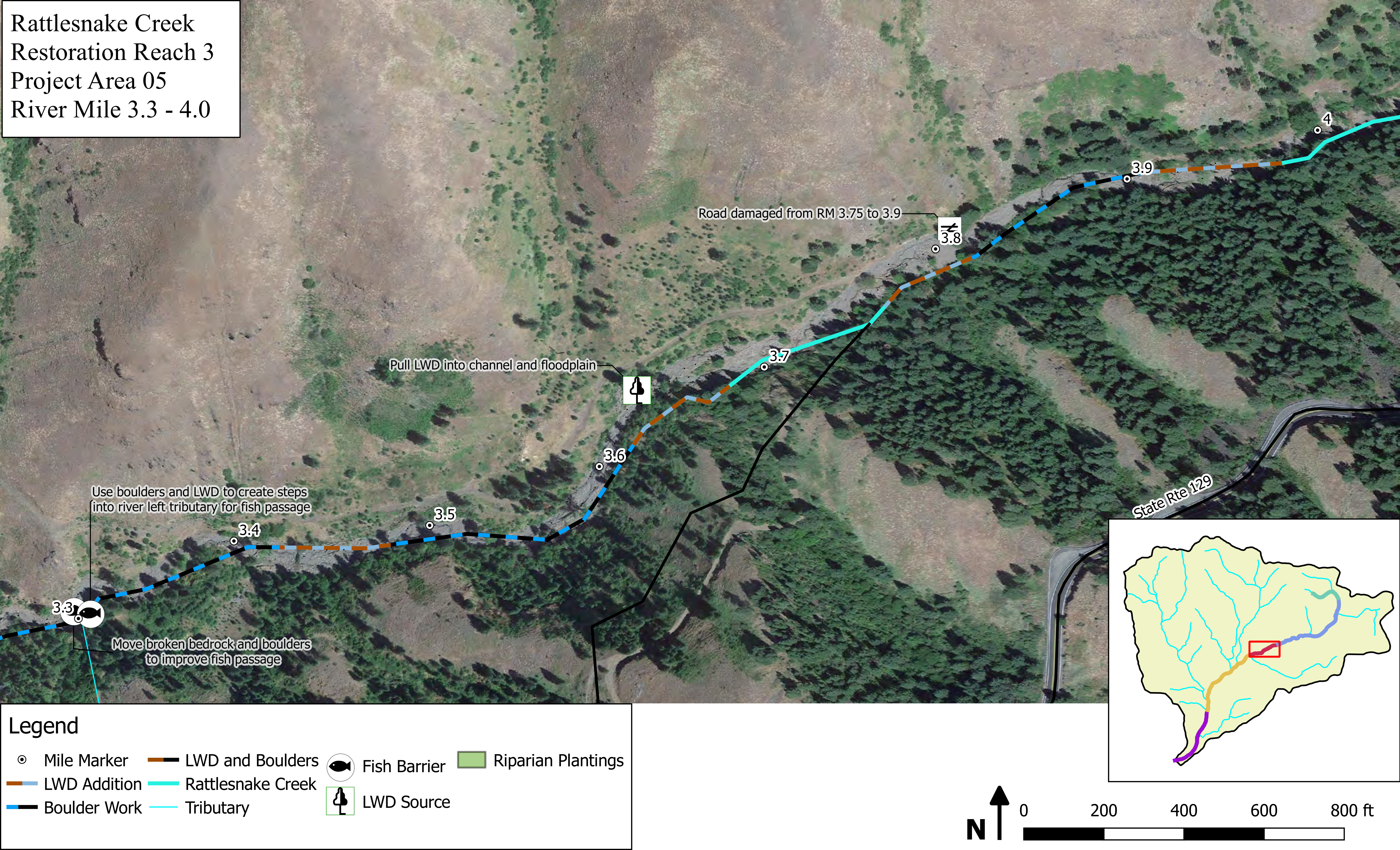

Rattlesnake Creek
Restoration Reach 2
Project Area 03
River Mile 1.9 - 2.2
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Weed control and plantings
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
2.2
2.1
2
1.9
Rattlesnake Cr Rd
Highway 129
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0 100 200 300 400 ft

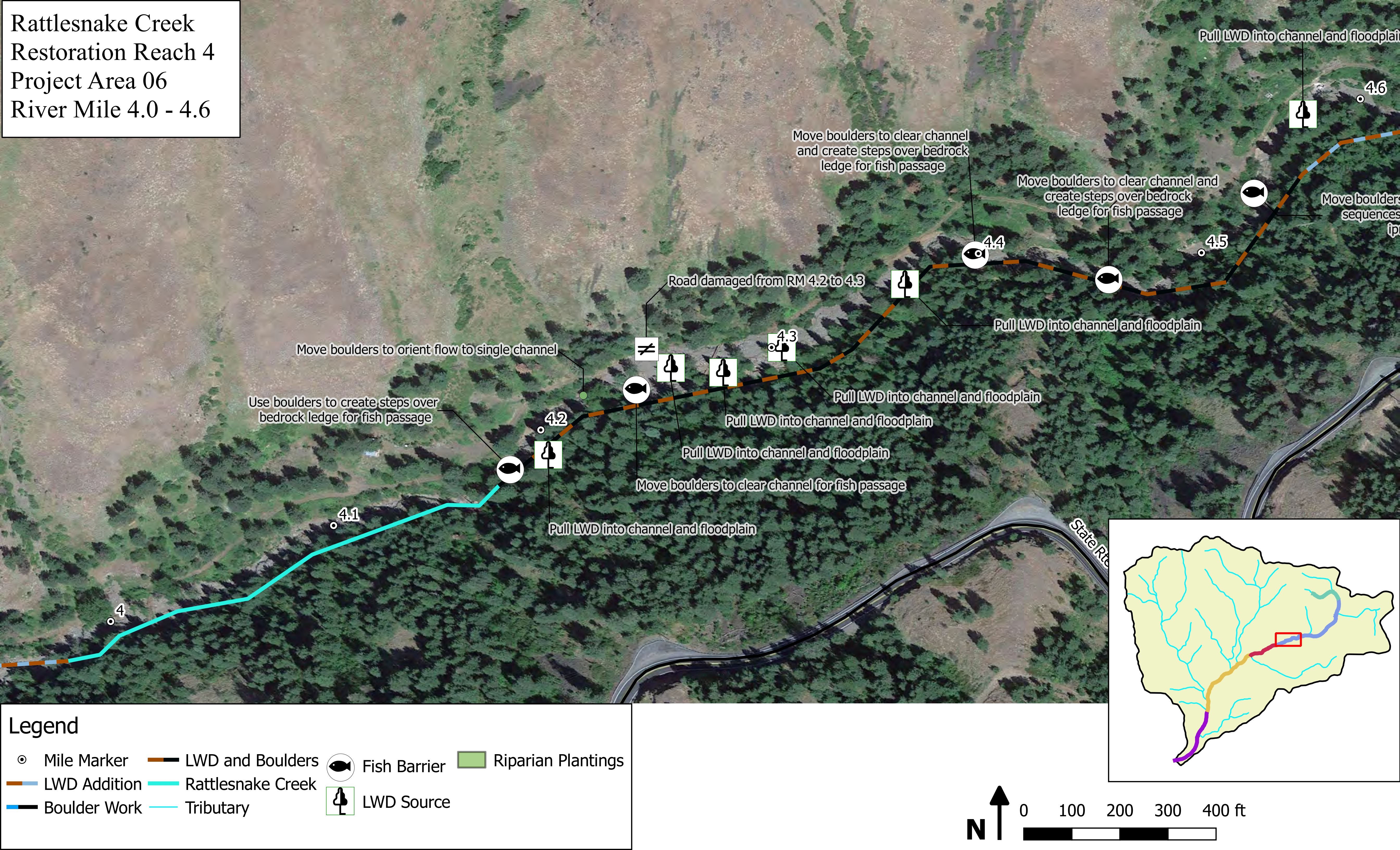

Rattlesnake Creek
Restoration Reach 2
Project Area 03
River Mile 2.2 - 2.4
2.5
2.4
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
2.3
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
2.2
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
2.1
Pull LWD into channel and floodplain
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
100
200
300
400 ft

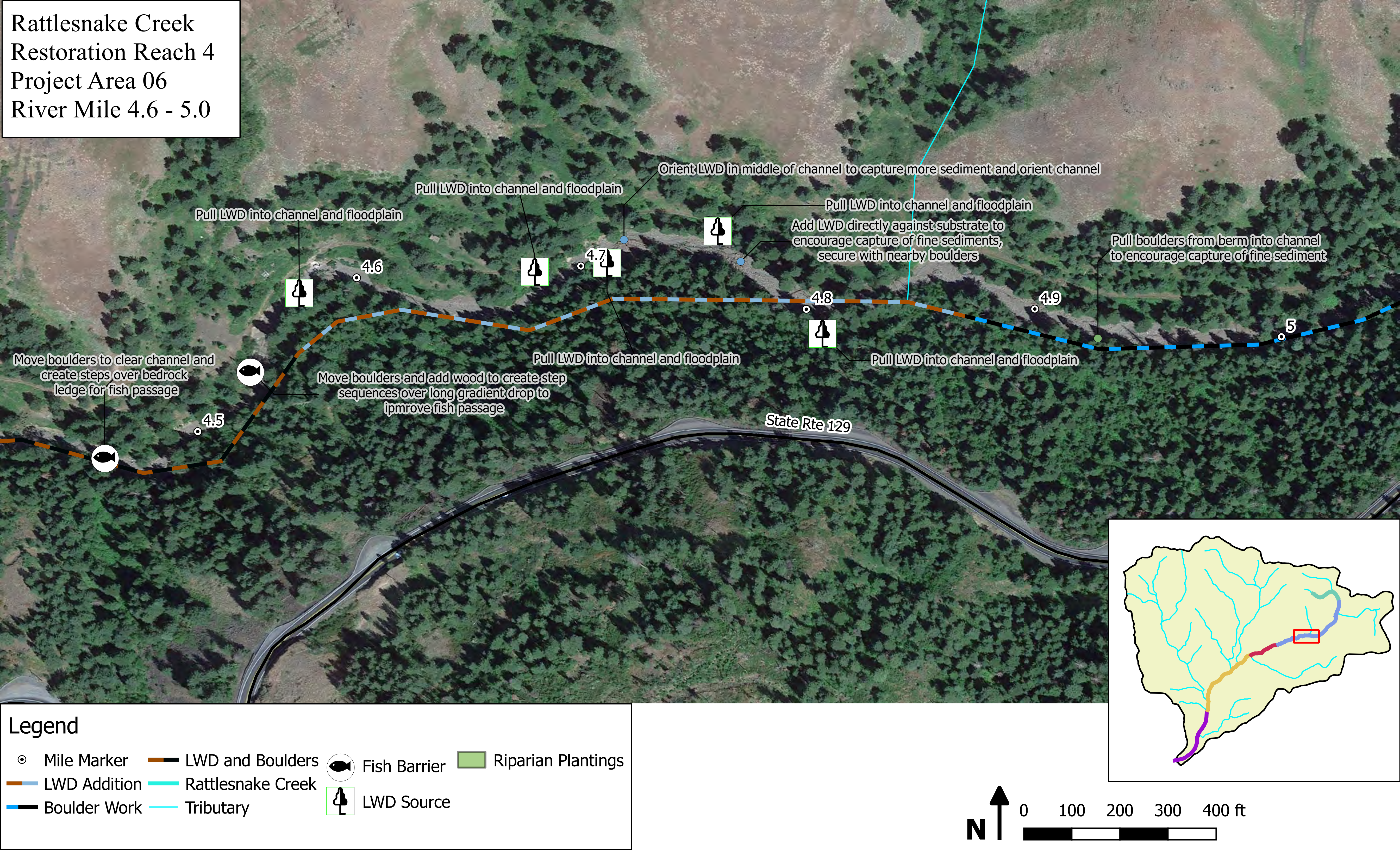


Rattlesnake Creek
Restoration Reach 2
Project Area 04
River Mile 2.4 - 2.8
2.8
2.7
2.6
2.5
2.4
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
and floodplain
Highway 129
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
100
200
300
400 ft

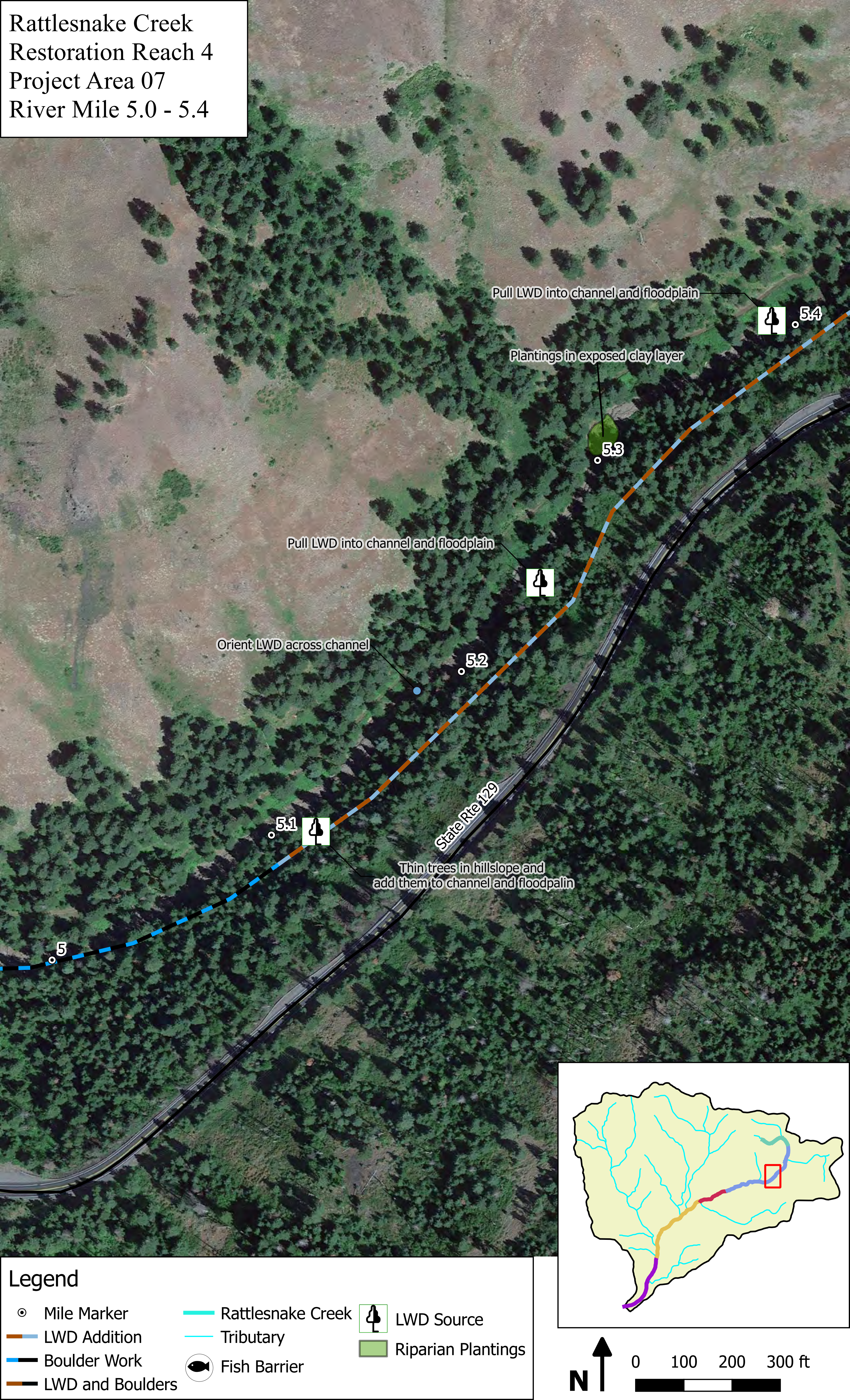

Rattlesnake Creek
Restoration Reach 2
Project Area 04
River Mile 2.8 - 3.3
Use boulders and LWD to create steps
into river left tributary for fish passage
Move broken bedrock and boulders
to improve fish passage
3.4
3.3
3.2
3.1
3
2.9
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
100
200
300
400 ft


Rattlesnake Creek
Restoration Reach 3
Project Area 05
River Mile 3.3 - 4.0
Road damaged from RM 3.75 to 3.9
Pull LWD into channel and floodplain
Use boulders and LWD to create steps into river left tributary for fish passage
Move broken bedrock and boulders to improve fish passage
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4
State Rte 129
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
200
400
600
800 ft

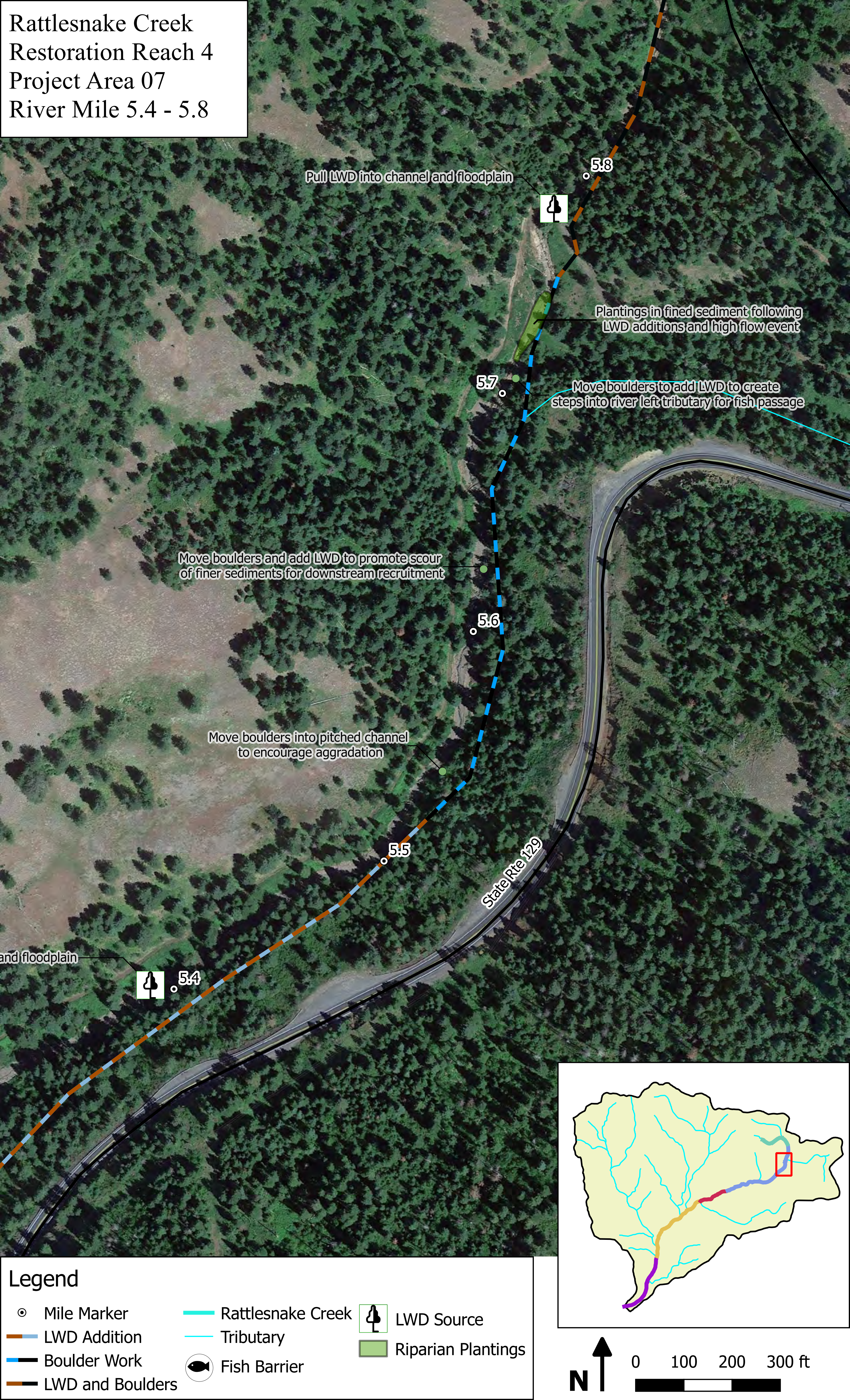

Rattlesnake Creek
Restoration Reach 4
Project Area 06
River Mile 4.0 - 4.6
Move boulders to clear channel and create steps over bedrock ledge for fish passage
Move boulders to clear channel and create steps over bedrock ledge for fish passage
Road damaged from RM 4.2 to 4.3
Pull LWD into channel and floodplain
Move boulders to orient flow to single channel
Use boulders to create steps over bedrock ledge for fish passage
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Move boulders to clear channel for fish passage
Pull LWD into channel and floodplain
4
4.1
4.2
4.3
4.4
4.5
4.6
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0 100 200 300 400 ft

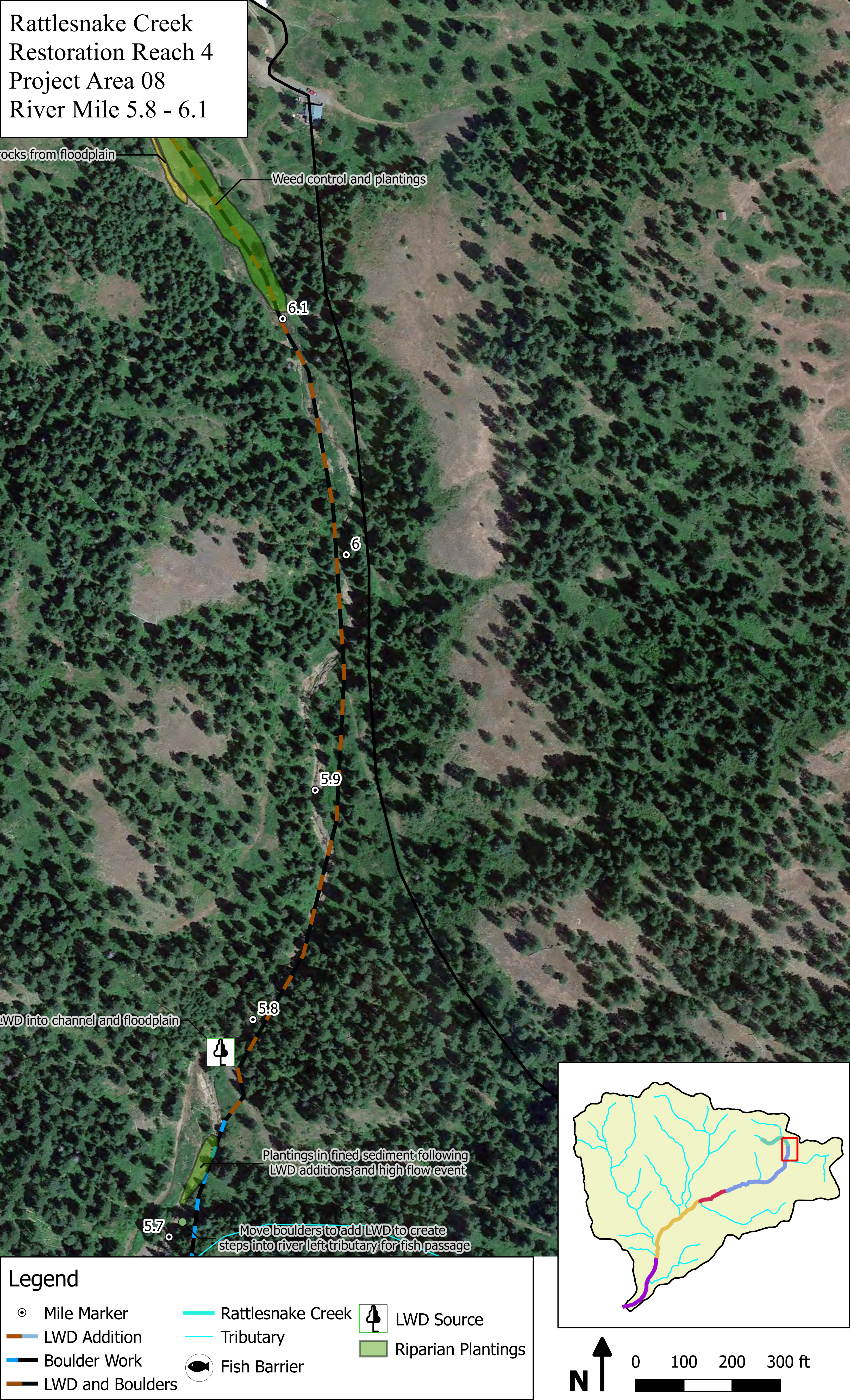

Rattlesnake Creek
Restoration Reach 4
Project Area 06
River Mile 4.6 - 5.0
Orient LWD in middle of channel to capture more sediment and orient channel
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
Add LWD directly against substrate to encourage capture of fine sediments, secure with nearby boulders
Pull boulders from berm into channel to encourage capture of fine sediment
4.6
4.7
4.8
4.9
5
4.5
Move boulders to clear channel and create steps over bedrock ledge for fish passage
Move boulders and add wood to create step sequences over long gradient drop to ipmrove fish passage
Pull LWD into channel and floodplain
Pull LWD into channel and floodplain
State Rte 129
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
100
200
300
400 ft

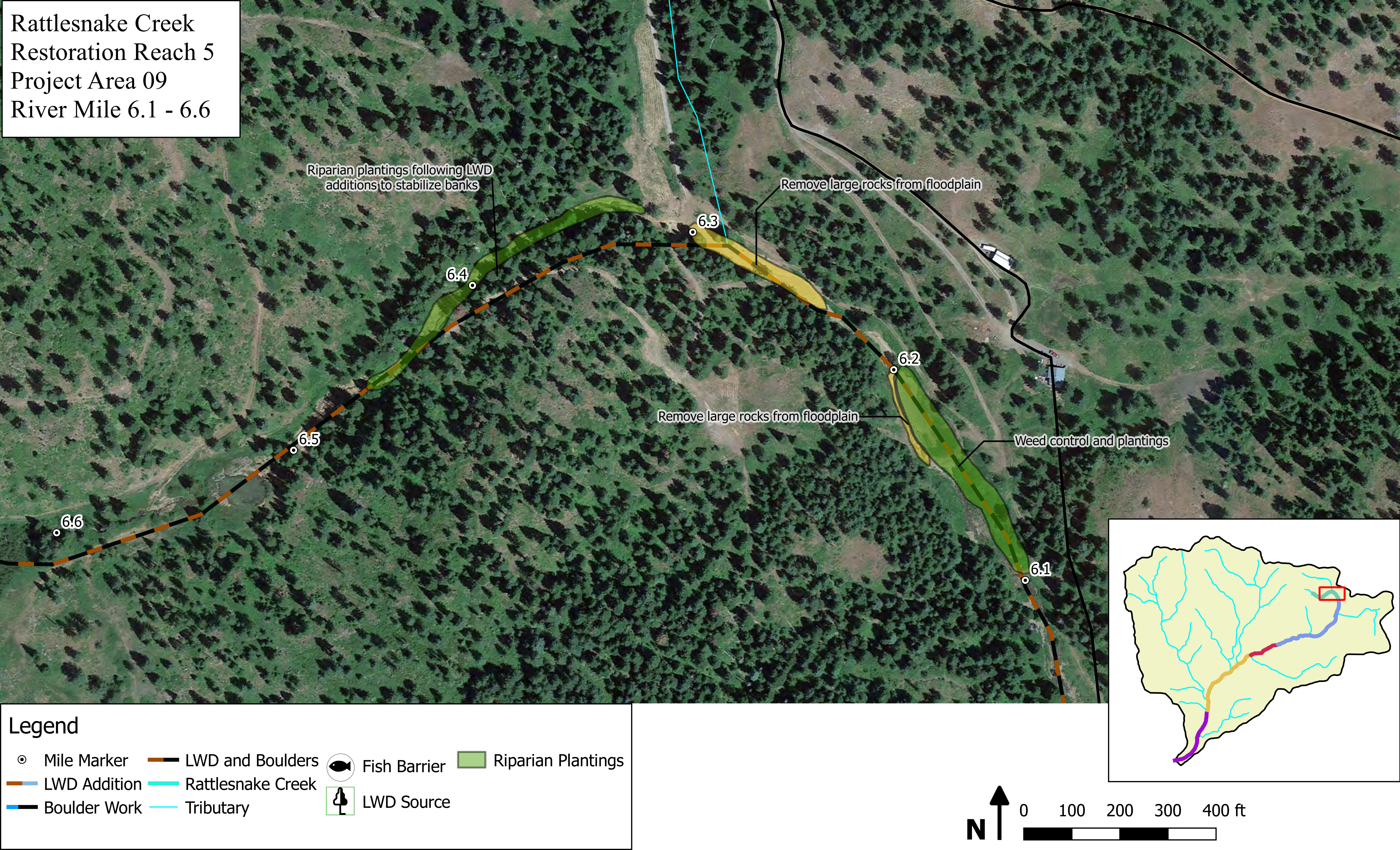
Rattlesnake Creek Restoration Reach 4 Project Area 07 River Mile 5.0 - 5.4

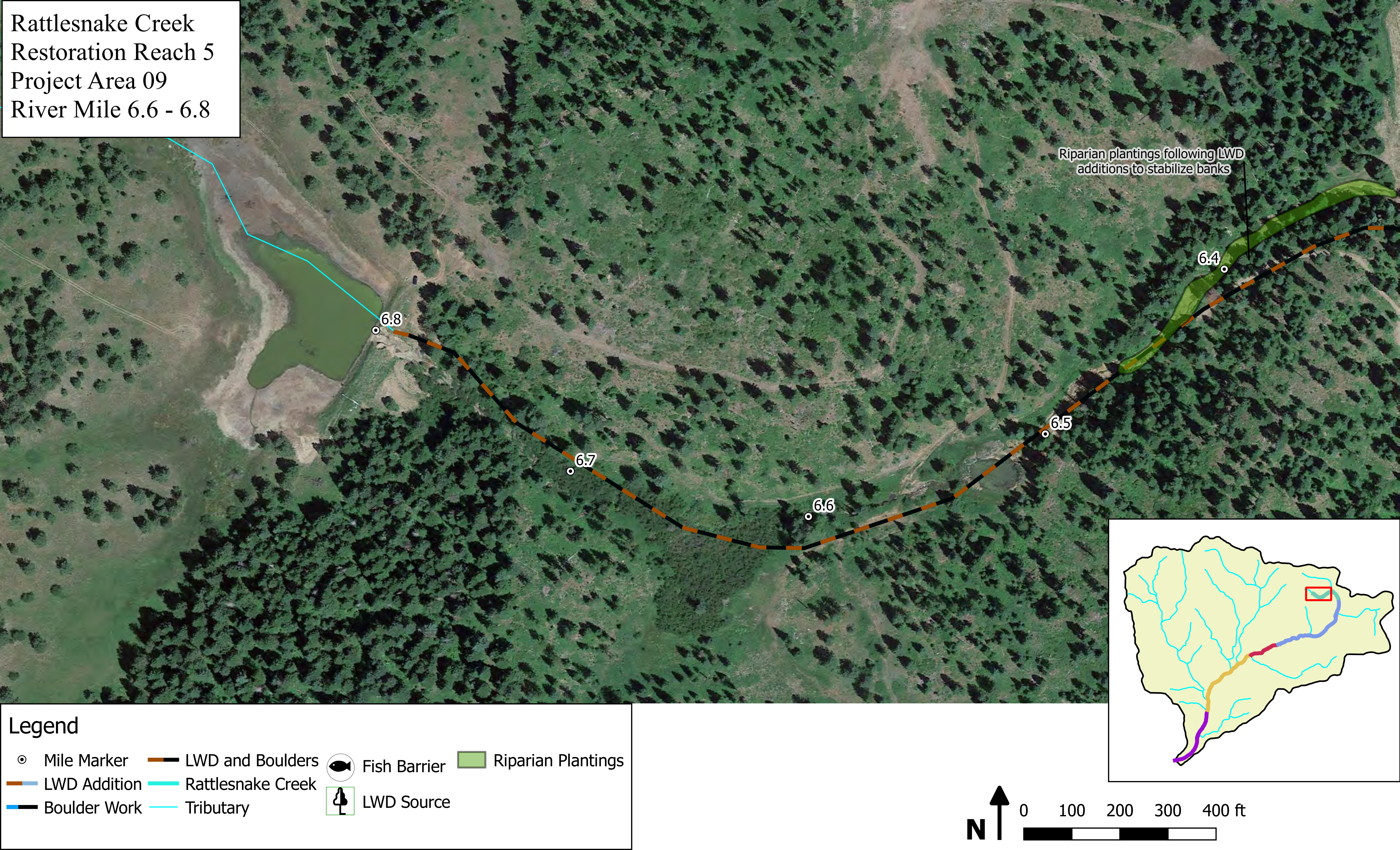


Rattlesnake Creek Restoration Reach 4 Project Area 07 River Mile 5.4 - 5.8




Rattlesnake Creek
Restoration Reach 4
Project Area 08
River Mile 5.8 - 6.1
ocks from floodplain
Weed control and plantings
6.1
6
5.9
5.8
LWD into channel and floodplain
Plantings in fined sediment following LWD additions and high flow event
5.7
Move boulders to add LWD to create steps into river left tributary for fish passage
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
100
200
300 ft


Rattlesnake Creek
Restoration Reach 5
Project Area 09
River Mile 6.1 - 6.6
Riparian plantings following LWD additions to stabilize banks
Remove large rocks from floodplain
Remove large rocks from floodplain
Weed control and plantings
6.1
6.2
6.3
6.4
6.5
6.6
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
100
200
300
400 ft


Rattlesnake Creek
Restoration Reach 5
Project Area 09
River Mile 6.6 - 6.8
Riparian plantings following LWD additions to stabilize banks
6.4
6.5
6.6
6.7
6.8
Legend
Mile Marker
LWD Addition
Boulder Work
LWD and Boulders
Rattlesnake Creek
Tributary
Fish Barrier
LWD Source
Riparian Plantings
N
0
100
200
300
400 ft